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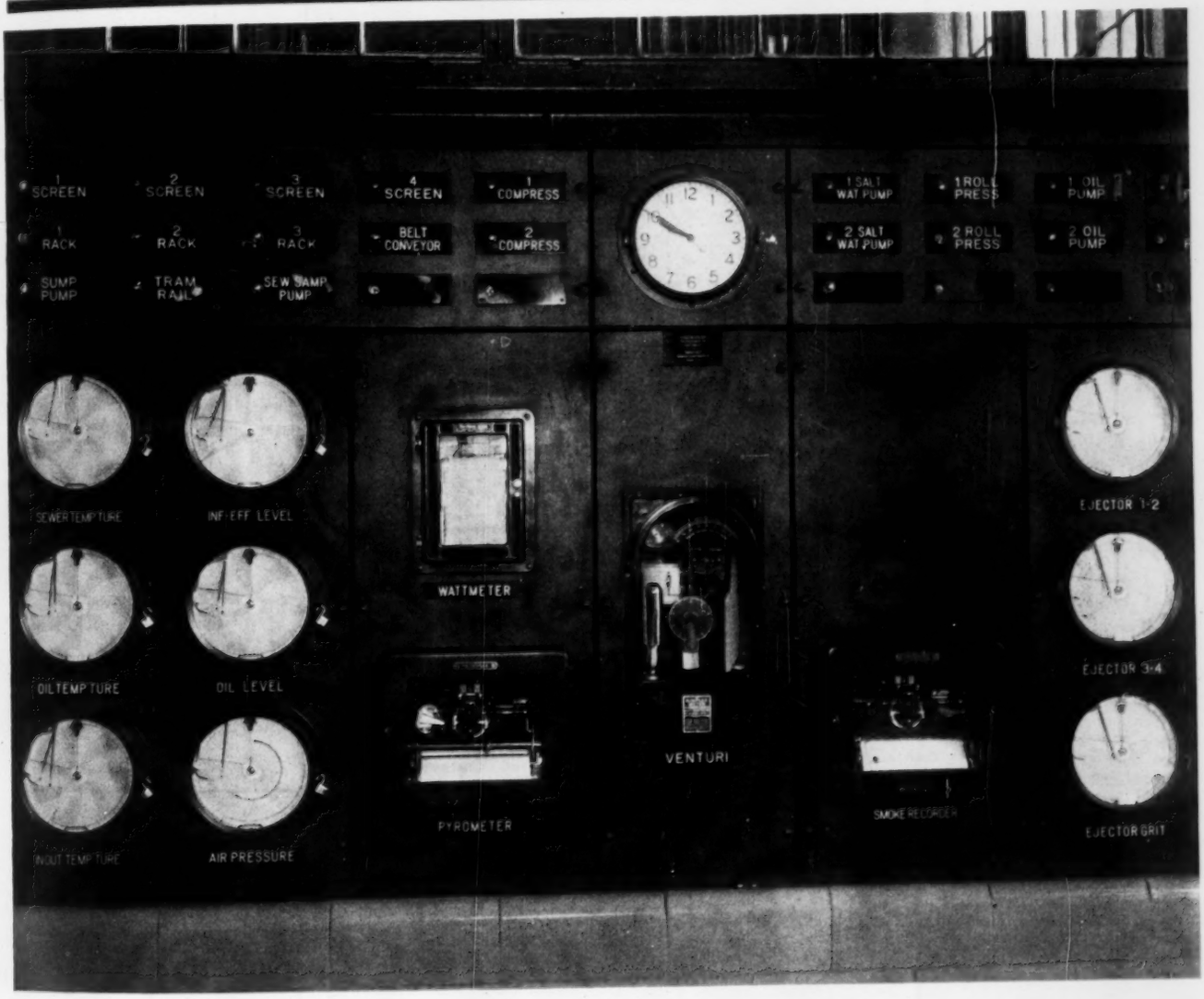
THE MAGAZINE OF MEASUREMENT AND CONTROL

VOLUME 7 MAY, 1934 NUMBER 5



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Although the author made the improvement of indicators his principal work for many years (developing the DeJuhasz Indicator as well as others not bearing his name) his recent years as Assistant Professor of Engineering Research at Pennsylvania State College have evidently been largely devoted to finding new uses for what he calls "normal types" of indicators for special applications. His book should prove useful in every shop and laboratory where variable pressures have to be known. Firearms people who deal with extremely high pressures lasting a thousandth of a second, ammonia-compressor people who deal with comparatively slow variations, and many other classes of technicians, will all find Prof. DeJuhasz talking straight to them in their own language and telling them of ingenious methods they all can use profitably.

One reads this book with delight and astonishment at the remarkable advances made in recent years, and with admiration for the author's lucid presentation of every conceivable angle of his subject.

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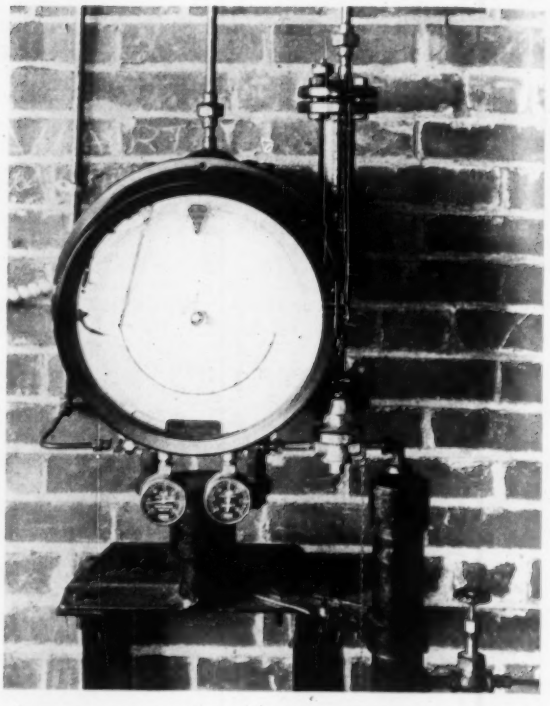

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A Flow STABILOG at the Shell Refinery in Montreal

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INSTRUMENTS

EDITORIAL COMMENT

In This Issue

Each of this month's two feature articles is devoted to a specialized branch of the ever-expanding science of Measurement; each represents a useful contribution by a competent specialist; and both Messrs. **Benedict** and **Hayward** present detailed expositions.

In the March instalments of the electrical instrument series, the principal measuring elements were described. How some of these are employed for the **measurement of current and of voltage** is the subject of this month's instalment.

Instrument manufacturers have not allowed the depression to prevent them from developing new models—even radically new types—as witness this month's lengthy **New Instruments** Section.

In Coming Issues

An article on the inelastic properties of "elastic" members of instruments, presenting the latest data on deviations from perfect elasticity and how to minimize them.

Another correlating recent European developments in metering orifices, many of which are decidedly worth knowing on this side of the pond.

Another describing the role of Instrumentation in a fast-growing new industry.

An extraordinary brain-child proposing a rational method of filing the ideas contained in *Instruments* (and in other technical journals) and of finding them when you want them!

And several specialized measurement articles whose authors are now putting them in final shape.

The Front Cover

Not many decades ago "sewage" was an almost unmentionable word. Science discovered values going to waste. Engineering developed disposal plants. Finally, Instrumentation automatized these plants and created pleasant working conditions. The front cover testifies to progress achieved jointly by the Westchester Sewerage Commission and instrumenticians.

Instrumentation Benefits Both Capital and Labor

PROPAGANDISTS of all shades from red to silver are at it loud and strong. *Instruments* receives its share of mimeographed publicity from various movements, but as a technical journal it will not take sides in political, racial, geographic or class discussions—so long as the discussers stick to their specialties. When any of them start blaming automaticity for the world's ills, however, we do not hesitate to protest.

It seems to us that some highly-publicized orators and writers start fruitless controversies to keep their names in the papers and to profit thereby—at the expense of hard-working citizens. We suspect that two or three pompous asses who made the front page by hurling wild accusations knew very well that there was not an iota of truth in their sensational "disclosures."

Two things are certain in connection with current propaganda: (1) Most of the sensational speeches, articles and editorials are built up of words and expressions which have been twisted until they have lost their original meanings; and (2) most of the inflammatory orators and writers cunningly use such words and expressions to gain unfair advantages. It has come to the point that the moment a racketeer is collared by justice he hires a ghost writer to play him up as a "patriot" "persecuted" by "communists." In spite of the traditional American sense of humor, love of fair play and compassion for the under-dog—perhaps *because* of these national traits—there is danger that ill-used words will set off unbridled emotions.

Unfortunately, such terms as "labor saving" and "technological unemployment" are in that category. Of all the nonsense belched out of the filthy mouths of prejudice-inciters, the most dangerous to our industrial civilization is the anti-science and anti-machinery propaganda.

Don't make the mistake of underestimating its danger. You may see through its fallacy, but you are one of a scant five million Americans who do. The rest of the population lacks definite technical knowledge and therefore can have its emotions played upon by slogans until it believes that black is white, that science creates poverty. We have heard many women express this belief, and we have heard several journalists declare that Americans are more susceptible to propaganda than other peoples. It behooves us all to keep on proclaiming that—

Instrumentation reduces the sum total of waste and drudgery, thereby enabling people to have more and better foods, clothes, houses, books, cars and goods of all kinds, and also to have more and more leisure. Instrumentation enables employers to pay high wages and to make the profits on which government must largely depend for "endowing leisure" and maintaining humanitarian and social-betterment agencies.

—M. F. BEHAR

ERRATA

In Fig. 1, page 64, last issue, the galvanometer should be connected *right* and *left*, not top and bottom. We hope all readers immediately detected a draftsman's slip—which we forgot to look for. Sorry!

At the end of the caption of Fig. 32-22, page 76, last issue, there should have been added a credit to *The Bristol Co.*, manufacturers of the instrument shown. Don't blame Mr. Borden: all our fault!

Bridge Methods for Measuring Dielectric Power Factor and Capacitance

By F. R. BENEDICT*

SINCE the Schering bridge is a relatively recent development, not generally taught even in electrical engineering courses until less than ten years ago, it might have remained a complete mystery even to most of those concerned with measurements of electrical properties. One useful thing about Benedict's article, therefore, is that it differs from most technical papers in that the author unblushingly describes the circuit before going on to show how and why this circuit should be modified to facilitate measurements of power factor and capacity of dielectrics under field conditions. That he leads up to his own Laboratory's developments, without describing others, is a touch of loyalty which does not detract from the worth and timeliness of his article. Besides, he scrupulously appends a comprehensive list of references. Among these, No. 16 is no doubt the one to consult for details of the "Schering galvanometer" so briefly mentioned in the article.

1. INTRODUCTION

FOR determining the electrical characteristics of insulating material, in either simple or composite form, the dielectric power factor and capacitance test is the best single test which can be made. Many power companies and users of insulating materials are making regular routine tests on their insulation. The location and reconditioning or replacement of faulty or poor insulation is paying dividends by making possible better maintenance of service.

Dielectric power factor capacitance methods are of two general classes, those methods which employ direct deflection instruments and those which utilize balance methods with more sensitive deflection instruments.

Direct deflecting instruments require frequent calibration, are subject to inaccuracies due to wave form, are of low range with high sensitivity or of high range with low sensitivity making necessary a number of instruments, and in general are difficult to read accurately.

Balance methods embodying the bridge principle may be made highly sensitive without loss of portability or general utility. Portable a.c. galvanometers are commercially available which compare in sensitivity with the best d.c. instruments, are sturdy, positive in indication, readily portable, do not require calibration and are insensitive to wave form.

Contrary to opinion, power factor measuring methods are not difficult in elementary theory. The operation of the power factor bridge is simple and an operator with only a few hours' experience will obtain results consistently and accurately.

2. THEORY OF NETWORKS

Power factor measuring methods ordinarily utilize a bridge principle with the advantage of the null method of detection. The general 4 branch impedance network is shown in Fig. 1. The circuit contains in its branches: resistance, inductance and capacitance alone or in combination. The inductances of the branches are made as small as possible in the common power factor bridge networks. The branches thus contain resistance and capacitance alone or in combination. The network is supplied at A and B by a pure sine wave voltage. A sensitive detector is connected across C and D.

Consider first the case of $Z_1 = R_1$, $Z_2 = R_2$, $Z_3 = R_3$, $Z_4 = R_4$ where R_1, R_2, R_3 and R_4 are pure non-inductive resistances. For detector current $I_D = 0$ the ordinary Wheatstone bridge balance obtains and

$$R_1 R_4 = R_2 R_3$$

If Z_1, Z_2, Z_3 and Z_4 are the symbolic impedance functions of the different branches, then the symbolic balance equation for $I_D = 0$ is

$$Z_1 Z_4 = Z_2 Z_3$$

Remembering that $Z = R + jX$ and allowing each side to operate on an arbitrary vector r we obtain

$$(R_1 + jX_1)(R_4 + jX_4)\, r = (R_2 + jX_2)(R_3 + jX_3)\, r$$

If the above equation is treated algebraically the relations existing at balance between the branch constants are

$$(R_1R_4 - X_1X_4) + j(X_1R_4 + X_4R_1)\, r = (R_2R_3 - X_2X_3) + j(R_2X_3 + R_3X_2)\, r.$$

Now when two vectors are equal their effective resistance and reactance components are equal, so that

$$R_1R_4 - R_2R_3 = X_1X_4 - X_2X_3$$

and

$$X_1R_4 - X_3R_2 = X_2R_3 - X_4R_1$$

are the conditions which must be fulfilled by the branch resistances and reactances. If $X_1X_4 = X_2X_3$ the two conditions to be fulfilled are that

$$X_1X_4 = X_2X_3 \quad \text{and} \quad R_1R_4 = R_2R_3$$

These equations show that the resistance and reactance terms must independently fulfill the ordinary Wheatstone bridge balance condition. Two adjustments of the branch impedances must be made, for in dealing with alternating quantities, phase as well as magnitude must be taken into consideration.

This general theory applies to most of the power factor bridges in use at the present time. The simple theory does not take into account ground capacitance or cross capacitances between the different arms. This may be allowed for by inserting the pertinent terms into the impedance equation. In general these residuals are balanced out or compensated for in the bridge network and do not appear in the bridge network equations.

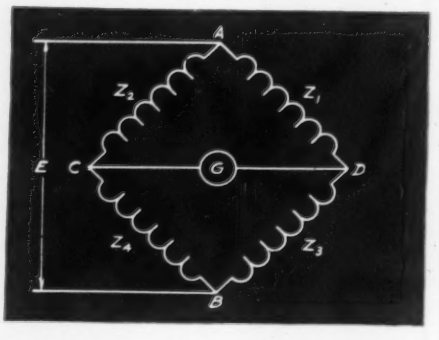

Fig. 1. The general four branch impedance network.

3. THE SCHERING BRIDGE

The Schering bridge circuit in its simplest form is shown in Fig. 2. C_1 is the test specimen. C_2 is a standard capacitor (air or compressed gas). R_3 is a non-inductive resistance variable from 0 to 1111.1 ohms. R_4 is a fixed non-inductive resistance of 265.5 ohms (60 cycles). C_4 is a low loss standard

*Laboratory Eng., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

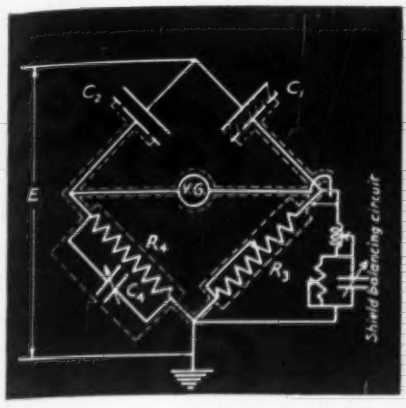

Fig. 2. Schematic diagram of the Schering bridge with simple shielding.

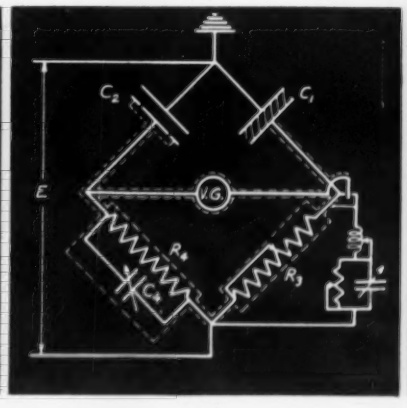

Fig. 3. Schematic diagram of the inverted Schering bridge with simple shielding.

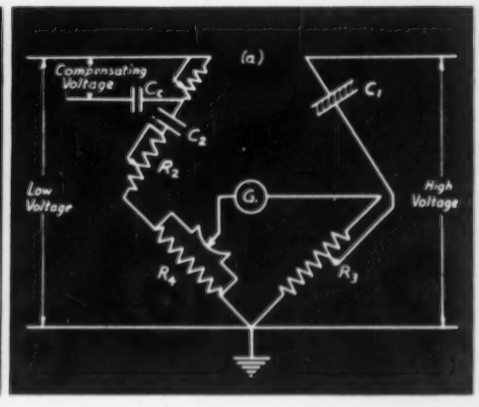

Fig. 4. Schematic diagram of the Atkinson bridge.

capacitor, variable from 0 to 11.11 mfd. V.G. is a sensitive vibration galvanometer, preferably of the Schering type. The voltage supply E should be a sine wave voltage as pure as it is possible to produce. The balance equations of this network are easily derived. Writing the branch impedance operators

$$Z_1 = R_1 + \frac{1}{j\omega C_1}\ ;\ Z_2 = \frac{1}{j\omega C_2}\ ;\ Z_3 = R_3\ ;\ Z_4 = \frac{1}{\frac{1}{R_4} + j\omega C_4}$$

Applying the symbolic balance condition of the preceding section $Z_1\ Z_4 = Z_2\ Z_3$ and inserting terms

$$\left[R_1 + \frac{1}{j\omega C_1}\right]\left[\frac{1}{\frac{1}{R_4} + j\omega C_4}\right] = R_3\left[\frac{1}{j\omega C_2}\right]$$

Reduction of this equation gives

$$R_1 - j\left[\frac{1}{\omega C_1}\right] = \frac{R_3\ C_4}{C_2} - j\left[\frac{R_3}{\omega\ R_4 C_2}\right]$$

Equating effective resistance and reactance terms

$$R_1 = R_3\left[\frac{C_4}{C_2}\right]$$

and

$$C_1 = C_2\left[\frac{R_4}{R_3}\right]$$

The loss angle ϕ of the tested capacitor C_1 is

$\phi = \tan^{-1} \omega C_1 R_1 = \omega\ C_4 R_4$

Then

Power Factor $= \text{Cos}\ \theta = \sin\ \phi = / = \tan\ \phi = \omega\ C_4 R_4$

For a 60 cycle voltage $\omega = 377$ and $R_4 = 265.5$ ohms so

$$\text{Power Factor} = \frac{C_4}{10}\ \text{(Power factors below 10\%)}.$$

$$\text{Power Factor} = \text{Sin}\ \tan^{-1}\frac{C_4}{10}\ \text{(Power factor over 10\%)}.$$

C_4 in both of these equations is in microfarads. The standard high voltage capacitor C_2, used with this particular bridge at voltages below 100 kv., has a capacitance of 140 x 10^{-12} farads. Resistance R_4 is 265.5 ohms (60 cycles) so

$$C_1\ \text{(Micro micro farads)} = \frac{37200}{R_3}$$

A standard capacitor of 51.5 $\times$ 10^{-12} farads is available for use at voltages greater than 100 kv. The formula for C_1 is changed accordingly to $\frac{13{,}670}{R_3}$. In testing low voltage high capacitance samples, high capacitance standards are desirable for high bridge sensitivity.

In order that stray capacitance to ground and inter capacitance between arms may be minimized, R_4, R_3, C_3, R_2 and C_1 are carefully shielded. By means of an earthing device, the shields are brought to galvanometer potential, practically eliminating all ground effects from these parts. Ordinarily a Schering tuned vibration galvanometer is used as a detector. Extremely-high sensitivity may be obtained by careful tuning.

The balance for power factor and capitance requires two simultaneous adjustments. A null reading on the galvanometer is obtained by varying R_3 and C_4 until the null balance relation is fulfilled. Power factor and capacitance is obtained by inserting these values of R_3 and R_4 in the formulas. Power factors may be measured to an accuracy of 10^{-4}, corresponding to a power factor of 0.01%.

4. THE INVERTED SCHERING BRIDGE

An examination of Fig. 2 shows that a grounded sample cannot be tested with the regular Schering bridge. Much field testing requires a ready method for testing grounded samples such as circuit breaker bushings and transformer bushings. For such tests the portable Inverted Schering bridge is available. Fig. 3 shows a schematic diagram of the bridge connections. This bridge differs from the Schering in that the ground and high voltage connections are reversed. The R_3 and R_4 arms must be insulated for full test voltage of 13.8 kv. In order to eliminate stray capacitance the shielding circuit is raised to galvanometer potential.

The bridge is made very compact by building the standard capacitor C_2 as an integral part of the case. The capacitance between the inner and outer case is used for C_2. The shielding adjustment, R_3, C_4, R_4 and the galvanometer are placed in the inner case. Adjustments are made with long micarta shafts which go through the guard of the inner case. Operation is identical with the Schering bridge. The basic formulas are the same for power factor and capacitance. The capacitance of C_2 is about 215 $\times$ 10^{-12} farads so

$$\text{Power Factor} = \frac{C_4}{10}\ \text{(Power factor below 10\%)}.$$

$$\text{Power Factor} = \text{Sin}\ \tan^{-1}\frac{C_4}{10}\ \text{(Power factor over 10\%)}.$$

and

$$C_1\ \text{(micro-micro farads)} = \frac{57{,}082.5}{R_3}$$

Power factor may be measured to an accuracy of 10^{-4} corresponding to a power factor of 0.01%.

This bridge is extremely useful for measuring the power factor and capacitance of transformer bushings without dropping the lead which ordinarily goes up through the bushing to the top terminal. All that is necessary for making a test of this kind is to insulate the lead from the inside of the bushing by means of a micarta tube or other insulation. The bushing is then connected to the high voltage lead and the transformer lead to the shield. The difference in voltage is never more than a few volts so no trouble results. Such tests may be made without dropping the oil level in the transformer tank or disconnecting the transformer lead inside the tank. The tests are made with rapidity and low cost.

5. THE ATKINSON BRIDGE

In 1925 Atkinson applied the bridge principle in a new way, as shown by Fig. 4. He opened the network at (a) and supplied one branch of the bridge at high voltage and the other branch at low voltage. C_2 may then be a low voltage high capacitance mica standard.

The method of detection is radically different in that it employs the a.-c. galvanometer which is phase selective. It is possible to measure power factor and capacitance independently of each other. Only two adjustments are necessary, so tests may be made with great rapidity.

Operation of the bridge is simple. A standard high voltage capacitor is inserted at C_1. The galvanometer is made sensitive for capacity and voltage applied. R_3 is set so that a null balance on the galvanometer is obtained by a value of R_4. The galvanometer is then set sensitive for power factor and balance made with the compensating resistance R_c. This balance is made to bring both sides of the bridge in phase. Record R_3 and R_4. Insert the test sample at C_1 and rebalance for capacity of the test sample with R_3 and R_4 arms. Power factor balance is made with R_2. The values of R_3, R_4 and R_2 are recorded.

The equation of balance may be worked out by following the principles already presented. If R_2 is in series with C_2 the power factor is given by the equation,

$$\text{Power Factor} = \text{Cos } \theta = \text{sin tan}^{-1}\ \omega R_2 C_2$$

where R_2 is the inserted series resistance.

R_2 is placed in parallel with C_2 for power factors greater than 20%. The power factor for the parallel connection is

$$\text{Power Factor} = \text{Cos } \theta = \text{sin tan}^{-1}\ \frac{1}{\omega R_2 C_2}$$

where R_2 is the inserted parallel resistance.

The capacitance of the test sample is obtained from the test readings of the standard capacitor and test readings of the sample.

The capacitance of the sample in micro microfarads when the capacitance of the standard capacitor is in micro microfarads is given by

$$C\ (\text{Sample}) = \frac{R_4\ (\text{Sample}) \times R_3\ (\text{Standard Cap})}{R_4\ (\text{Standard Cap}) \times R_3\ (\text{Sample})} \times \text{Cap. of Standard.}$$

If R_2 is in series with C_2 the capacitance obtained is the equivalent series capacitance of the sample. If R_2 is in parallel with C_2 the capacitance obtained is the equivalent parallel capacitance. This must be taken into account in figuring dielectric constants.

The bridge values are as follows:

Standard Capacitor $= 45.1 \times 10^{-12}$ farads.

$R_2 = 0$ to 99,999.99 ohms.

$C_2 = .266 \times 10^{-6}$ farads.

$R_3 = 0$ to 1000 ohms, tapped at 0.2, 0.3, 0.5, 1.0, 10, 50, 100, 200, 500 and 1000 ohms.

$R_4 = 6$ or 60 ohms.

The slidewire is graduated from 0 to 1000 by 10's.

$R_c = 99.9$ ohms.

$C_c = 8 \times 10^{-6}$ farad.

Upon inserting the constants the power factor equation reduces to

$$\text{Power Factor} = \text{Cos } \theta = \text{sin tan}^{-1}\ \frac{R_2}{10^4}\ \text{(Series conn. of } R_2\text{)}$$

$$\text{Power Factor} = \text{Cos } \theta = \text{sin tan}^{-1}\ \frac{10^4}{R_2}\ \text{(Parallel conn. of } R_2\text{)}$$

This bridge is ideal for mass testing of samples, as only one balance need be made on the standard capacitor if the voltage is not changed. Grounded samples may be tested if a completely shielded transformer is available. An accuracy of 10^{-4}, corresponding to 0.01% power factor, is easily obtained. With a suitable standard capacitor the bridge may be worked up to 300 kv. without trouble. A bridge of this type has been used in the Westinghouse Laboratories for four years. It has never been out of service except for high voltage standard capacitor repairs.

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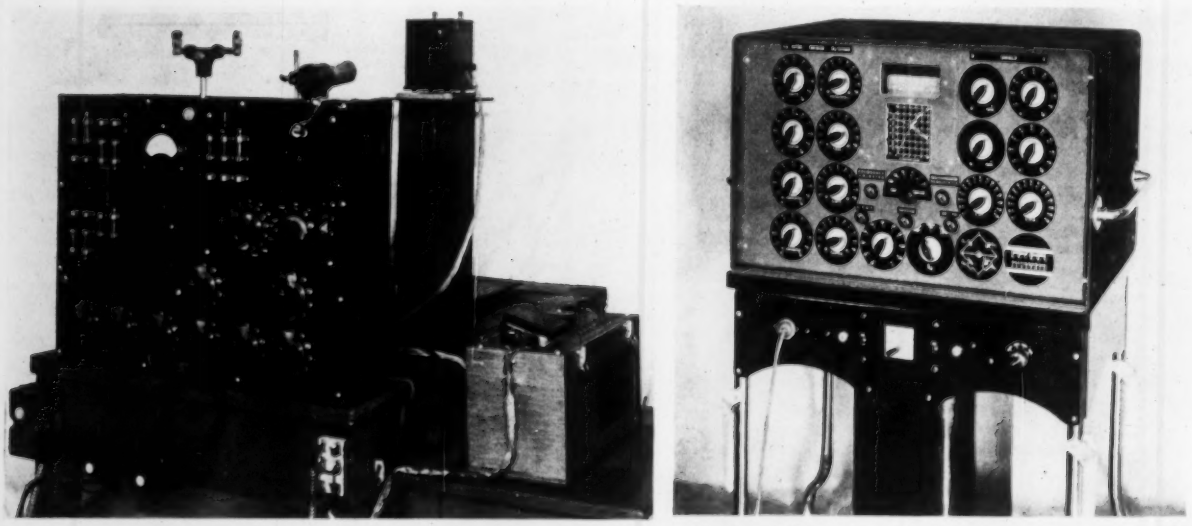

Fig. 5. At left, the Atkinson bridge set up in the laboratory; at right, the inverted Schering bridge manufactured by Westinghouse.

A Multiple-Speed Standard for Calibrating Hand Tachometers

By H. N. HAYWARD*

THERE are at least two reasons why a program of frequent periodic testing of speed measuring instruments is often not a regular part of plant or laboratory procedure, even though the need for such a routine is understood and appreciated. Both reasons are fundamentally economic; accuracy and precision must be purchased at a price. The reasons are: (1) reliable standardizing equipment is usually expensive, and (2) the manipulation is apt to be slow and rather tedious, resulting in excessive time charges accruing against the calibration account. Of the two, the second reason is probably of the greater importance except, perhaps, in instances where only comparatively few speed measuring instruments are in use.

It should be mentioned that, as far as *calibration* is concerned, all types[8,9,10,11] of speed measuring instruments may be included in either one of two general groups. The first group may be classified as the averaging type, which measures the average speed over a certain time interval; and the second group as the instantaneous type, which gives an indication depending only upon the instantaneous speed within the ability of the instrument to respond to rapid fluctuations of velocity.

The calibration of each of these two general groups should be considered separately. The reading of an instrument of the instantaneous type may indicate a speed variation of an appreciable amount during the interval of the operating cycle of an instrument of the averaging type, thus making it impossible to check an instrument of either type against one of the opposite type unless the speed of the test apparatus can be maintained constant within very narrow limits for the complete duration of each individual comparison. It also is apparent that two instruments of the averaging type need not give identical readings, although both may be correctly calibrated, if the operating cycles of the two instruments are not of the same length and the speed varies slightly during a test. It can be readily seen, too, that it is necessary to read two instruments of the instantaneous type simultaneously if they are to be compared and a reliable constant speed source is not available.

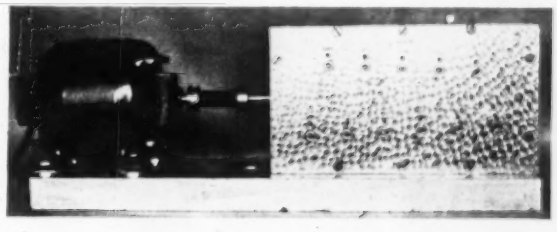

Fig. 1

Calibration actually involves only the comparison of the indications of a standard with those of the instrument being tested but it is an obvious requirement that both instruments read exactly the same quantities. An instrument of the averaging type must be calibrated against a standard capable of measuring the average speed for the operating interval of the test instrument. The fact that this period is only of three or six seconds duration limits the accuracy of the calibration for all instruments classed as speed indicators, in which the counter and time mechanisms are combined so readings may be made directly in r.p.m. on a single scale. Use of a longer period of measurement for the standard instrument will not increase the accuracy of the calibration unless a constant speed can be maintained for the complete duration of the test period. Likewise, the calibration of an instantaneous type instrument requires a standard which will give an instantaneous reading to be compared with a simultaneous reading of the instrument being tested. Only if the speed of the testing device can be held rigidly constant, which will result in the average and instantaneous speeds being equal, can a single standard instrument be used to calibrate both types of speed measuring instruments.

The inevitable conclusion is: a device for general testing and calibrating of speed measuring instruments should be capable of operation at an inherently constant speed when the adjustments required for each test are completed.

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It is the function of the standard instrument to show at all times the actual speed of the testing apparatus. Any desired speed can be readily obtained and conveniently determined by the use of a definitely known constant speed source to operate the testing apparatus in connection with a positive ratio drive, relegating the variable speed standard instrument to the classification of an unnecessary accessory.

An accurate and convenient standard of speed is now almost universally available. The error is less than 0.5% under normal conditions and usually does not exceed 0.25 or 0.3% except at infrequent intervals. An additional superiority is that the speed is definitely known, eliminating the need for any form of standard speed measuring instrument. It is an established fact that electric clocks are reliable timepieces, which is adequate proof that the frequency of a clock-controlled commercial power system averages exactly 60 cycles over a period of several hours. Under normal operating conditions the frequency at any instant does not deviate more than $\frac{1}{4}$ cycle from the average value, which is equivalent to an error of 0.42%. A synchronous motor, therefore, can be relied upon as a standard of speed which is satisfactory for testing all but a few of the precision types of speed measuring instruments.[2,3,4,5,6,7]

Equipment for testing and calibrating speed measuring instruments usually consists of a variable speed drive and a standard instrument arranged to give the theoretically true indication to be compared with the actual indication of the test instrument. The variable speed may be provided by:

(1) a variable speed motor designed to operate over the required range of speed;

(2) a constant speed motor combined with an infinitely variable ratio mechanical drive;

(3) a constant speed motor combined with a positive drive employing change gears and affording a range of speed in definitely fixed steps, but with only one speed available at a time.

The first two types possess several inherent disadvantages. It is necessary to "set" the speed for each test point. This is difficult to do unless a fine control adjustment is provided. Careful manipulation is always required. Manual control is usually relied upon to secure a constant speed so more or less continuous adjustment is a part of the calibration process. An important consideration is that readings of both the standard and test instruments must be made practically simultaneously at each test point. Observational errors may be made in reading either, or both, of the instruments. Because the standard must operate over a reasonably large range of speed, the accuracy cannot be as good as would be possible with a restricted range standard. The third type is free from most of the disadvantages associated with the first two types. An important advantage is that the greater accuracy possible only with a restricted range standard instrument may be realized. A compensating practical disadvantage is the necessity of stopping the apparatus to shift or change the gears to give each new speed.

A device utilizing a small synchronous motor as a prime mover as well as a standard of speed must include a train of gears as the means of obtaining the several required speeds. Replacing the usual type of gear train (employed to give only one of the several speeds at a time) with a fixed gear train affording several speeds simultaneously will overcome the most serious disadvantage of this type of apparatus. Additional change gears can be provided to enlarge the total range beyond the limits of each fixed group of speeds.

A standard speed device designed for checking hand speed measuring instruments has been in use for the past year in the electrical laboratory of the University of Illinois and has been

found satisfactory. A side view of the exterior of the complete apparatus is shown in Fig. 1. The arrangement of the interior is evident from an inspection of Fig. 2. Eleven speeds are provided, from 1000 r.p.m. to 2000 r.p.m. in steps of 100 r.p.m. With this device it is possible to complete in a minimum amount of time the frequent routine tests in the usual operating ranges of the speed measuring instruments used in the laboratory. It should be noted that all the driven shafts rotate in the same direction. Clockwise rotation is secured on one face of the gear box and counterclockwise on the other. With this standard speed device it is possible to calibrate two instruments at the same time without inconvenience; and even four small ones, though this would be a mere "stunt."

The installation of change gears with a 2 to 1 step-up ratio between the motor and the gear box would give the device a range from 2000 to 4000 r.p.m. in steps of 200 r.p.m. A 2 to 1 reduction would provide a range between 500 and 1000 r.p.m. in 50 r.p.m. steps. The lowest speed in any range is 50% of the highest speed, and each step amounts to 5% of the highest speed. Only one type of gear train is described here.

The actual design used may vary considerably for each particular application. The idea of using a fixed-speed prime mover and a positive-drive transmission may not be entirely original although the many advantages possessed by such an arrangement are certainly not generally appreciated.

The motor used to operate this device is a standard ⅙ h.p., 4 pole, 1800 r.p.m. machine of the non-excited synchronous type. The gear train and housing were designed to be built with the equipment available and for the lowest possible cost. The essential purpose was to determine if a device of this type would give satisfactory service under the particular conditions to be met.

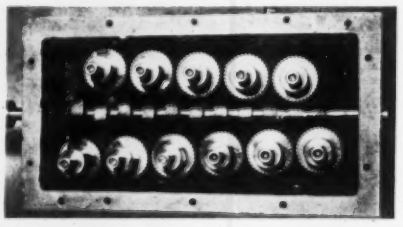

Fig. 2

The device has been used satisfactorily with three types of hand speed measuring instruments (tilting ring tachometers, speed indicators, and tachoscopes) of standard commercial manufacture. The load resulting from the simultaneous operation of several tachometers has not been sufficient to cause the synchronous motor to pull out of step. A synchronous motor is an excellent prime mover for a device of this kind because the instantaneous speed varies only during the actual time the load is changing. As the load increases the rotor is retarded slightly compared to its former position relative to the magnetic field, but the average speed remains constant for a constant supply frequency. Sudden changes in the load may cause the motor to "hunt" or oscillate above and below the mean speed but these oscillations are quickly damped out by the damper winding provided to start the motor as well as prevent hunting.

Hunting of the synchronous motor will have no effect on the calibration of instruments of the averaging type because the average speed of the motor does not change unless the hunting is sufficiently severe to cause the motor to pull out of step. The pointer of instantaneous type instruments may vibrate slightly as a result of hunting, but the inertia of all the moving parts of the instrument will tend to minimize the amplitude of such vibration.

Rubber friction tips are used to drive the hand instruments in many of the usual applications, so this standard was designed for friction driving of the tachometers by providing countersinks on both ends of each driven shaft. Friction drives are not satisfactory for heavy tachometers or for the lower speed ranges of the light hand tachometers because of the relatively large driving torques required.[8] It actually is necessary, however, to calibrate any multiple-range instrument on one range only because each separate range is obtained by using a suitable fixed ratio drive and an appropriate scale constant; and neither of these can influence the operating characteristics of the instrument.

A speed pin screwed into a threaded hole in the center of each driven shaft of the standard speed device can be used to establish a positive drive[8] for special work in connection with either a driving pin and a slotted collar or a flexible shaft for transmitting the rotation to the tachometer.

It is possible to design a device similar to the one already described but capable of a much higher accuracy. There is at least one limited-range instantaneous type speed recorder on the market with a sensitivity of about 0.02% and an accuracy of approximately 0.035%.* If used in connection with the standard speed device it would serve to indicate the actual speed of the synchronous motor at every instant and permit corrections to be applied to the normal speeds on account of variations in the supply frequency. In most cases the frequency changes relatively slowly under normal operating conditions due to the considerable inertia of the rotating machines on the power system. Increased accuracy would result at the expense of slowing down the testing procedure and increasing the labor cost of each calibration.

A better plan would be to use either a prime mover capable of being accurately adjusted over a limited range of speed, or a positive drive transmission with a variable ratio to compensate for any change in the speed of the prime mover in connection with a sensitive speed indicator similar to the recorder mentioned above to permit convenient adjustment of the speed to exactly the desired value. With proper design, manual control of the speed should result in satisfactory operation under most operating conditions in addition to minimizing the initial cost of this type of standard apparatus.

Automatic speed control would tend to improve the accuracy as well as facilitate rapid calibration, and could be incorporated in the design for a reasonable increase in the original cost of the device. What constitutes reasonable cost can be the subject of a lengthy and involved discussion. At the present time many of the ordinary routine measurements made in connection with commercial or experimental tests involve errors much greater than is generally appreciated. Precision apparatus is expensive and often requires the services of a trained expert for best results. Compared to the usual complicated reference standard designed for primary precision work, I believe that an automatically controlled speed standard similar to the one mentioned would be reasonable in cost and satisfactorily accurate for most ordinary industrial and laboratory calibration purposes.

ADDENDUM—COMMERCIAL FREQUENCY CONTROL

The information I have gathered from some of the references listed in the bibliography, as well as from the experiences of engineers connected with some of the electrical operating companies, indicates that the frequency variation of a large power system will be within the limits specified except during periods of abnormal operating conditions. This limited variation may not apply to the ordinary operation of many of the systems. The following paragraph is given as one of the "Fundamental Requirements" listed in Brandt's paper[4] "Automatic Frequency Control":

"The apparatus should be sensitive and fast. It should not permit an error of more than 1/30 cycle to go unnoticed and it should not delay more than 10 seconds before making a move toward correction of the minimum error. Larger errors should be attacked more quickly."

The very fact that a more accurate standard is planned is an indication that the frequency control on a commercial power system does not provide a standard of speed of sufficient accuracy or dependability for exacting applications.

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*The Westinghouse Type RF Centrifugal Frequency Recorder with a range of from 59 to 61 cycles. According to the manufacturer this instrument has a sensitivity of approximately 1/100 of a cycle (equivalent to 0.0167%) and is accurate within 1/50 of a cycle (corresponding to 0.033%). A synchronous motor is used to drive the centrifugal element which actually indicates variations in speed. The relationship between frequency and speed being rigidly fixed by the synchronous driving motor, the instrument can be calibrated as a frequency recorder.

LETTERS TO THE EDITOR

Diligent Delver Discovers "Disturbing Discrepancy" 'tween U. S. & Europe

To the Editor:

Having been interested in the subject of fluid flow in pipes and through orifices for several years, I have familiarized myself to some extent with the writings of European investigators as well as American engineers and manufacturers who are interested in this subject. I have been particularly interested in the matters recently published in your magazine *Instruments* which I believe form distinct contributions to engineering literature.

I am calling your attention to what I believe to be one of the disturbing discrepancies between the American engineers and the European investigators which I have come across. I believe it worthy of your serious consideration and would appreciate your giving me your views on the matter.

The use of Reynolds' number has proven to be a useful and critical point in the whole field of fluid flow. In recent months many papers have been presented before the A.S.M.E. and have appeared in your own magazine in which Reynolds' number is used as one scale in coordinating plotting of curves. Wherever such use is made of Reynolds' number I have found the following universal description of the factors entering into the computation of that number:

R = Reynolds' number, a dimensionless quantity
D = A cross-sectional measure in feet
v = Velocity, feet per second
ρ = Weight density, pounds per cubic foot
μ = Absolute viscosity, pounds per square foot per second

All of the authors state that if consistent units are selected in any other system the Reynolds' number also will be dimensionless and identical. I should like to point out that the use of absolute viscosity and weight density are entirely inconsistent and lead to a number which is certainly not dimensionless and is not in accordance with Osborn Reynolds' description of his criterion. In order to make the number dimensionless, it is essential that if absolute viscosity in pounds per square foot per second is used, then mass density and not weight density must be used. It appears that American investigators almost universally miss this very essential point and I am sending you a hand-written sheet showing results of this inconsistency.

I am taking the liberty of addressing this letter to you because in using the data recently published I have gotten into serious difficulties in attempting to compare the results of various investigators and I believe that it would be a distinct contribution if some authoritative word could be published on the matter by *Instruments*.

1 Wall St., New York F. J. LEERBURGER
March 22, 1934

Referred to Pigott, Buckingham, Bean, Beitler, Conlee, Diederichs, Diehl, Gess, Kerr, Mason, Pardoe, Smith, Sprenkle, Stahl, Swift, Tuve, Van der Pyl, Weymouth . . . —ED.

Sheet enclosed with Mr. Leerburger's letter

Absolute System	Engineers' System
μ = absolute viscosity $= \dfrac{(\text{force})(\text{time})}{(\text{area})}$	
$\mu = \dfrac{(\text{poundal})(\text{second})}{(\text{foot})^2}$	$\mu = \dfrac{(\text{pound weight})(\text{second})}{(\text{foot})^2}$
$= \dfrac{(\text{pound mass})(\text{sec.})}{(\text{foot})^2} \times \dfrac{(\text{ft.})}{(\text{sec.})^2}$	$= \dfrac{(\text{pound mass})(\text{second})}{(\text{foot})^2} \times \dfrac{\text{ft.}}{\text{sec.}^2}$
$= \dfrac{(\text{pound mass})}{(\text{foot})(\text{second})}$	$= \dfrac{(\text{pound mass})}{(\text{foot})(\text{second})}$
ρ = mass density $= \dfrac{(\text{pound mass})}{(\text{foot})^3}$	ρ = mass density $= \dfrac{(\text{pound mass})}{(\text{foot})^3}$
ρ_B = weight density $= \dfrac{\text{poundals}}{(\text{foot})^3}$	ρ_B = weight density $= \dfrac{\text{pounds weight}}{(\text{foot})^3}$

Reynolds' number $= \dfrac{Dv\rho}{\mu}$ if computed in consistent units

D = feet	D = feet
v = feet/sec.	v = feet/sec.
ρ = mass density $= \dfrac{\text{pound mass}}{\text{foot}^3}$	ρ = mass density $= \dfrac{\text{lb. mass}}{\text{ft.}^3}$
μ = pound mass/foot second	μ = lb. mass/ft. sec.
$R = \dfrac{(\text{ft.})\left(\dfrac{\text{ft.}}{\text{sec.}}\right)\left(\dfrac{\text{lb. mass}}{\text{ft.}^3}\right)}{\dfrac{\text{lb. mass}}{\text{ft. sec.}}}$	$R = \dfrac{(\text{ft.})\left(\dfrac{\text{ft.}}{\text{sec.}}\right)\left(\dfrac{\text{lb. mass}}{\text{ft.}^3}\right)}{\dfrac{\text{lb. mass}}{\text{ft. sec.}}}$
$= 1$ ∴ dimensionless	$= 1$ ∴ dimensionless

Note what happens if μ is in lbs./ft.sec. units and ρ is weight density

Absolute System	Engineers' System
D = ft.	D = ft.
v = ft./sec.	v = ft./sec.
ρ_B = weight density $= \dfrac{\text{poundals}}{\text{ft.}^3}$	ρ_B = weight density $= \dfrac{\text{pounds weight}}{\text{ft.}^3}$
$\mu = \dfrac{\text{pounds mass}}{\text{foot second}}$	$\mu = \dfrac{\text{pounds mass}}{\text{foot second}}$
$R = \dfrac{(\text{ft.})\left(\dfrac{\text{ft.}}{\text{sec.}}\right)\left(\dfrac{\text{poundals}}{\text{ft.}^3}\right)}{\dfrac{\text{lbs. mass}}{\text{ft. sec.}}}$	$R = \dfrac{(\text{ft.})\left(\dfrac{\text{ft.}}{\text{sec.}}\right)\left(\dfrac{\text{pounds wt.}}{\text{ft.}^3}\right)}{\dfrac{\text{lbs. mass}}{\text{ft. sec.}}}$
$= \dfrac{\dfrac{\text{poundals}}{(\text{sec.})(\text{ft.})}}{\dfrac{\text{lbs. mass}}{(\text{sec.})(\text{ft.})}}$	$= \dfrac{\dfrac{\text{lbs. weight}}{(\text{sec.})(\text{ft.})}}{\dfrac{\text{lbs. mass}}{(\text{sec.})(\text{ft.})}}$
$= \dfrac{\text{poundals}}{\text{lbs. mass}} = \text{ft./sec.}$	$= \dfrac{\text{lbs. weight}}{\text{lbs. mass}} = (\text{ft./sec.})(32.2)$
this is NOT dimensionless	this is NOT dimensionless

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Ammeters and Voltmeters*

By PERRY A. BORDEN† and M. F. BEHAR**

In general, ammeters and voltmeters are practically identical in structure. As was pointed out, they may operate on substantially identical principles, each being essentially a current measuring device. The basic difference between the two usually rests in the proportioning of parts and in the connections to the circuit. The most logical treatment of measurement of current and voltage, then, would seem to be to take up first the connections of these instruments to the circuits in which they are used, and to point out the essential differences arising from these connections: This will be done. The discussion will be limited to direct-reading ammeters and voltmeters and their combinations—not to balance instruments, which will be treated later.

1. Ammeters—Ampere-turns

An ammeter is always connected in series with the line in which the current is to be measured. Therefore, the circuit of the instrument must be of sufficient carrying capacity to handle this current. In measuring elements wherein the moving part has no electrical connection with the external circuit, as in the induction type and the several moving-iron types, the problem is to have the current-carrying coil formed of a conductor with a cross-sectional area large enough to carry safely the measured current, and with a number of turns sufficient to produce a magnetic field adequate for the purpose. Thus, in instruments of the repulsion type, the full-scale value of an ammeter may be made a few milliamperes or it may be made several hundred amperes, merely by providing a coil to give the requisite ampere-turns with the measured current. An instrument giving a full scale deflection with 300 ampere-turns in the measuring coil may be built with a coil having a single complete turn which will give a full scale of 300 amperes, or with two turns for a scale of 150 amperes, or with three turns for 100 amperes, etc., the product of turns and full-scale amperes remaining at the value of 300, till with a relatively large number of turns the instrument may be given a scale of a few milliamperes. The limit lies in the increase in the impedance of the coil as the number of turns is increased and the wire correspondingly reduced in size to make room in the allotted space; and in ammeters for small currents the impedance of the instrument may become a serious factor in the measurement.

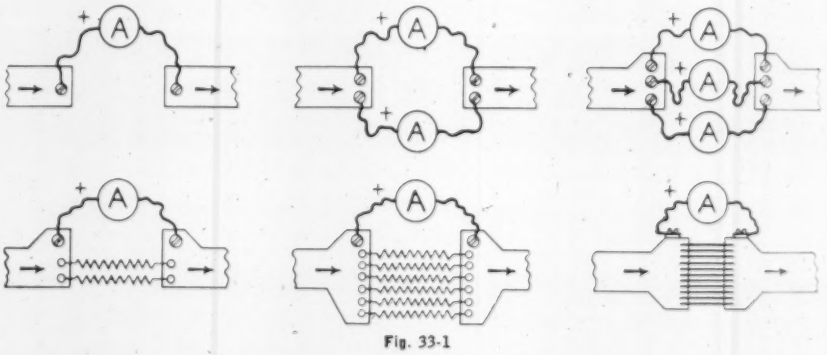

Fig. 33-1

2. Shunts and Leads

In the use as ammeters of instruments in which the measured current or a definite part of it must be carried into a moving circuit, there arises a problem due to the impracticability of leading currents of appreciable magnitude into the delicately constructed moving part. The usual limit is a few milliamperes for most indicating ammeters. The solution is analogous to that of measuring the flow of water in an aqueduct by placing a small water meter in a by-pass where the flow is always proportional. If a current to be measured is slightly beyond the range of a certain ammeter it is apparent that if two ammeters of identical impedance values are connected in parallel with each other the

*Fifth chapter (XXXIII) of Part Seven (Handbook of Industrial Electrical Measurements and Control) of Béhar's *Manual of Instrumentation*. See editorial announcement of this series on page A7 of November 1933 *Instruments*. A complete chapter of this new handbook will be published in each issue of *Instruments* throughout 1934 and 1935. Each chapter is subjected to a final revision, and then set in type, shortly before its appearance in this serial form, in order to assure that the subject matter is thoroughly up-to-date. This new book is not published serially in any other periodical. Entire contents copyright. To be issued in book form on or about Jan. 1, 1936.

†Member A.I.E.E. **Editor, *Instruments*

current will divide equally between the two, and each will read half the total current in the line. Similarly, if any number of ammeters of equal impedance be connected in parallel with one another, the current will divide equally among the several instruments, and the reading of one multiplied by the number of ammeters will represent the true value of the current. Since, however, but one of the instruments needs to be read, it is only necessary to use one measuring element, placing in parallel with it an impedance having a value equivalent to that of another element or group of elements in parallel, when the reading of the single ammeter multiplied by the proper constant will be a true indication of the total current in the line. These steps are all shown in Fig. 33-1.

The impedance unit which is placed in parallel with a movement for increasing its range is known as a shunt. While the use of a shunt of proper impedance value will give accurate results with an alternating-current ammeter, technical considerations make the use of shunts in a.-c. measurement generally inadvisable; and their use is confined almost entirely to combinations with movements of the permanent-magnet moving-coil type which are d.-c. movements, as was already pointed out. Mechanically, a shunt usually

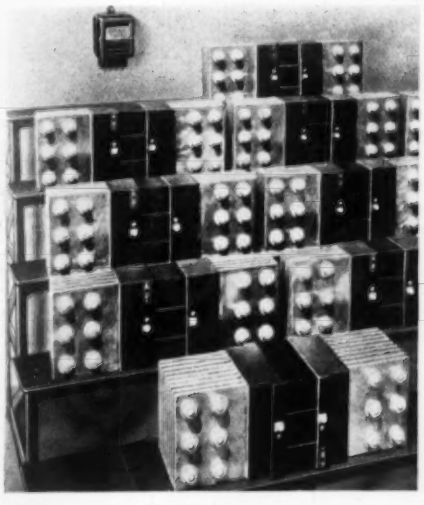

Fig. 33-2. Exhibit of large Sangamo shunts including one for 20,000 amp. Compare size with meter on wall.

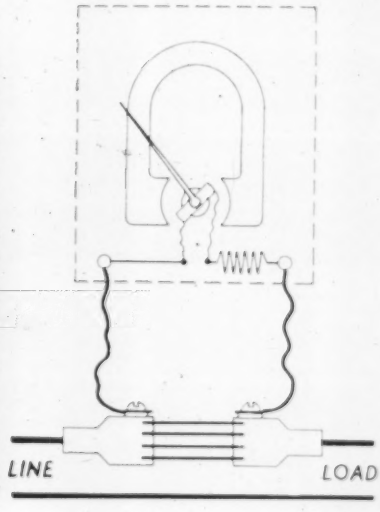

Fig. 33-3. Diagram of an ammeter with internal resistance and external shunt.

consists of a compactly constructed resistor of relatively low ohmic value, having the actual resistance unit made up of one or more strips of manganin or similar metal, with massive terminals of copper. Suitably heavy connection means for line current are provided, and separate binding screws for the ammeter leads are located where there will be the least error due to uneven current distribution in the terminal blocks. Fig. 33-2 shows commercial examples.

It is not the usual practice to connect the shunt directly across the moving coil of an instrument. A certain fixed resistance is generally placed in series with the movement, making of the instrument proper a millivoltmeter, and the combination connected across the shunt. This makes for permanency of calibration and tends to reduce temperature errors in the instrument. A low-range direct-current ammeter usually has its shunt enclosed in the case with the movement; but in high ratings, both switchboard and portable, the shunt is generally a separate unit, connected to the instrument proper by flexible leads. We must say that with regard to self-contained ammeters, different manufacturers have different notions of "low" and "high" ranges.

It formerly was the custom, where instruments were used with separate shunts, to adjust the instrument and shunt together without regard to interchangeability; but present practice is to adjust all instruments of a type to give full scale deflection with the same potential drop in millivolts at the terminals. Similarly, the shunts for these instruments are all standardized to give the same potential drop for full current, thus making interchangeable all shunts and all instruments of one type. The most common standard values for full-scale millivolt drop are 50, 100 and 200 millivolts.

When the shunt is separate from the instrument the leads are considered a part of the instrument proper; and they should never be cut or otherwise altered, without recalibrating the instrument. Breakage of a single strand in a shunt lead may introduce errors in the reading of the instrument; breakage of

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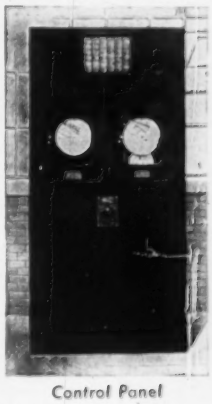

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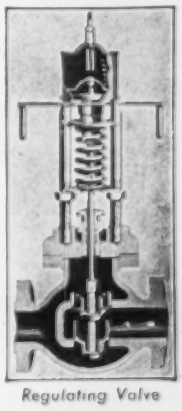

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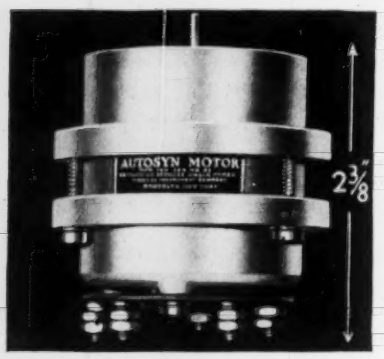

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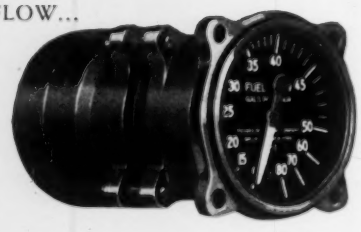

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several strands certainly will. Shunt leads should therefore always be treated with great care, not cut or strained or laid on the floor to be walked on. Shunt leads are most likely to develop defects at the point of attachment of the flexible cord to the metal terminal and the worst thing about these faults is that they are difficult to detect. In Fig. 33-4 is shown Borden's method of attaching terminals to leads, which has been found effective in eliminating breakage of strands at this point. The insulation is first carefully cleaned from the wire, so that when soldered there will be a negligible length of exposed conductor. Before soldering the joint a piece of varnished cambric tubing, 8,

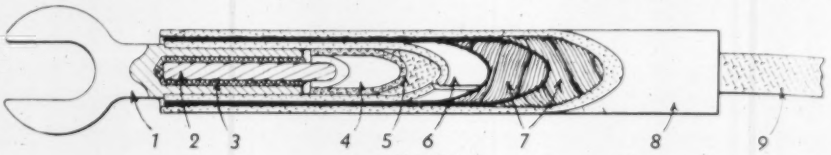


Fig. 33-4

somewhat larger than the outside of lead 9, is slipped over it. Soldered joint 3 is then made, and any gap which may exist between the metal of terminal lug 1 and the insulation of lead 9 is filled up with thread shellacked into place. If any material difference exists between the diameter of the lug shank and that of the lead, the smaller is built up with a thin serving of silk tape cemented or shellacked on. A piece of varnished cambric tube, 6, having an inside diameter the same as that of the joint, is then split lengthwise, slipped over the joint and served with one or more layers of silk or thin cotton tape 7, until a diameter is built up to fit the inside of outer varnished cambric tubing 8. This serving should be secured with a few stitches of thread and thoroughly soaked with shellac or a flexible cement, after which large tube 8 is forced into place as close as practicable to the lug. There is thus provided a joint between the flexible cord and the solid metal of the lug, which, while allowing reasonable bending, tends to prevent concentration of the bend at one point and thus eliminates the risk of breaking conductor strands by repeated flexing. At the same time there is no brittle insulating material to be crushed if accidentally stepped on.

A tricky source of error in shunted instruments lies in loose connections between terminal blocks and shunt leaves. Such faults, too, are very difficult

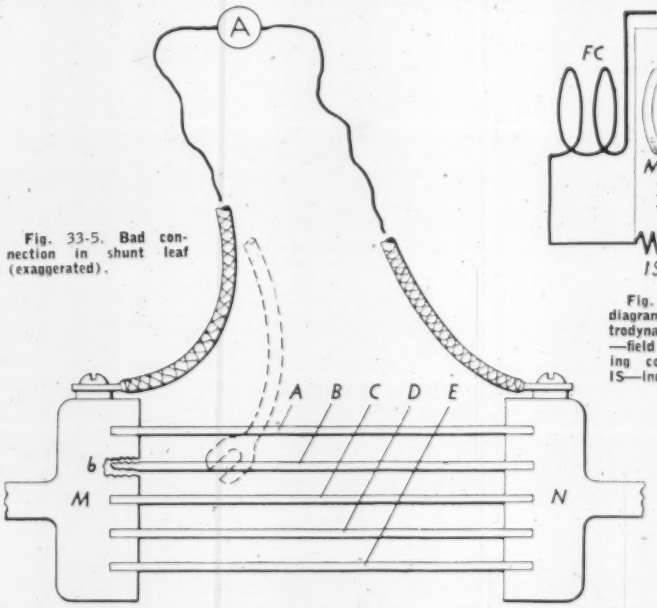


Fig. 33-5. Bad connection in shunt leaf (exaggerated).

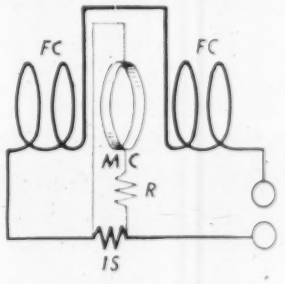


Fig. 33-6. Internal diagram of shunted electrodynamic ammeter. FC—field coils; MC—moving coil; R—resistance; IS—inductive shunt.

to detect by inspection, and generally can be found only by actual electrical tests. Fig. 33-5 illustrates this type of fault. Leaf *B* is shown as having developed a bad connection with block *M* at point *b*. If this amounts to an actual open circuit, the total resistance of the shunt between blocks M and N will be increased. If, for example, the number of leaves is 9, the total resistance will be 9/8 of the correct value, and the ammeter will read 1/8, or 12½%, high. A test for this condition may easily be performed by disconnecting one of the shunt leads and determining the relative potential drop on individual leaves while a steady current is passing. With the shunt in good condition the full drop across the shunt should be found by applying testing on any individual leaf. With an open circuit, as at *b*, this point on the leaf

will be at substantially the same potential as block *N*, and practically the full shunt drop will be registered between *B* and block *M*.

The abnormal potential drop introduced by a fault of this nature may make its appearance suddenly in an old shunt, and may be productive of mystifying and erratic effects. One of the writers, engaged on a test in a rather old direct-current station, found no fewer than seven out of twelve main feeder shunts (all of reputable makes) to have errors of this nature, the associated ammeter in one instance reading 35% high!

In making permanent installations of shunts on switchboards it is necessary that certain precautions be observed. The cables or buses to be connected to the shunts should be positioned in such a manner that the shunts are not exposed to mechanical strains. Wherever possible, the shunts should be placed horizontally with the leaves on edge, so that free circulation of air will be possible. With vertically disposed shunts the top terminal block is likely to become warmer than the other, with consequent possibilities of error due to thermoelectric effects. Such errors were sometimes serious in the old days, but today the use of manganin (which has a negligible thermoelectric coefficient against copper) has minimized them. In any event it is easy to ascertain whether a hot shunt is a source of thermoelectric error: cut off the current passing through the hot shunt and observe whether the instrument pointer returns to zero immediately or whether it (1) hovers above zero or (2) overshoots and hovers below zero, gradually coming to zero as the shunt cools. (Of course, this assumes absence of zero shift in the movement. The simple test for zero is to disconnect one of the shunt leads.)

3. Shunted A.-c. Ammeters

In ammeters of the electrodynamic type we find practically the sole instance where the practice of shunting for alternating-current measurements is carried out. Here the whole current is allowed to flow through the stationary coils, and a shunt is provided across the terminals of the moving coil. In order that the relative current distribution between the shunt and the moving coil shall be independent of frequency, the shunt is made with an inductance, so that the characteristic phase-angle of the shunt will be the same as that of the coil. Fig. 33-6 shows the internal connection system of such an instrument.

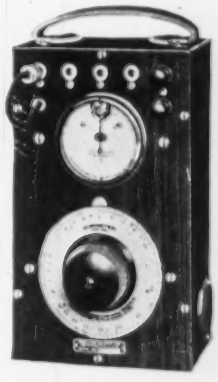
4. Voltmeters

In the use of an instrument movement as a voltmeter, it is common practice to limit the current in the measuring circuit by means of a relatively high resistance connected in series with the circuit, the whole being connected across the measured line. The current flowing through the movement will be governed by the resistance of the whole circuit so that, by adjusting the resistance to the proper value, the instrument may be given any desired range. In switchboard and portable indicating instruments with ranges up to about 750 volts it is common to include the resistor within the case.

For higher ranges the resistor, when used, is usually external to the instrument. A voltmeter whose scale is already complete for a given range may often have its range extended by use of a series resistor, known as a *multiplier*. It is usual, where a multiplier is employed, that the readings on one of the scales of the instrument (generally the highest) be multiplied by a constant quantity in order to obtain the true voltage value. Since the resistance of a voltmeter is generally very high relatively to its reactance, the phase-angle of a.-c. instruments (excepting of the induction type) is usually negligible, and the property of inductance may generally be neglected in calculations involving series resistors. A typical resistance value for d.-c. voltmeters may be taken as 1,000 ohms per volt, and for a.-c. voltmeters 100 ohms per volt.

5. Multi-purpose Instruments

With interchangeable shunts a single ammeter may of course be used for measurement of a wide range of currents, the scale either being calibrated and marked with several sets of numerals, or the readings being multiplied by suitable constants. Ammeters with self-contained shunts are built to have two or more ranges, the change from one range to another usually being accomplished by making use of different terminals, or sometimes by range-changing switches. Similarly voltmeters, particularly of the portable type, are frequently furnished with one or more tapped points on the self-contained series resistor, brought out to corresponding terminals and the several ranges marked on the scale (see Fig. 33-9). Cambridge supplies a d.-c. voltmeter comprising a high-sensitivity d'Arsonval "Unipivot" movement having a universal shunt, connected in a circuit having a total resistance of 40,000 ohms. Range



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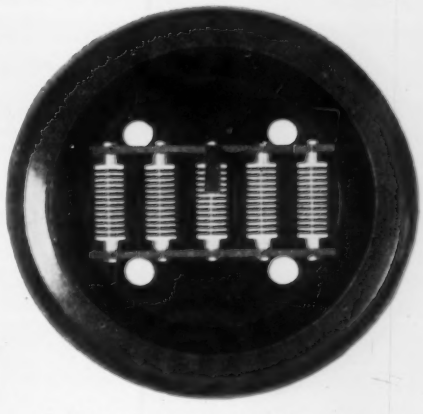

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6. Volt-ammeters

Since the measuring element of a voltmeter is substantially identical with that of an ammeter, it is practicable to provide a single movement with both shunts and series resistors, and the resulting instrument is not only suited for use as a voltmeter or as an ammeter, but several ranges of each may be provided. See Fig. 33-10. In making a single movement a compromise between that best suited for an ammeter and for a voltmeter, a certain degree of ac-

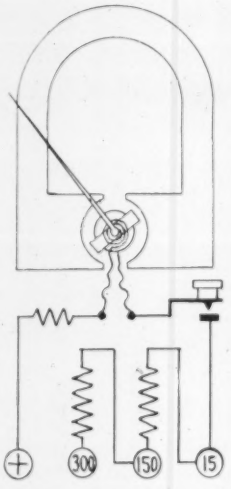

Fig. 33-9. Internal diagram of a multiple-range voltmeter.

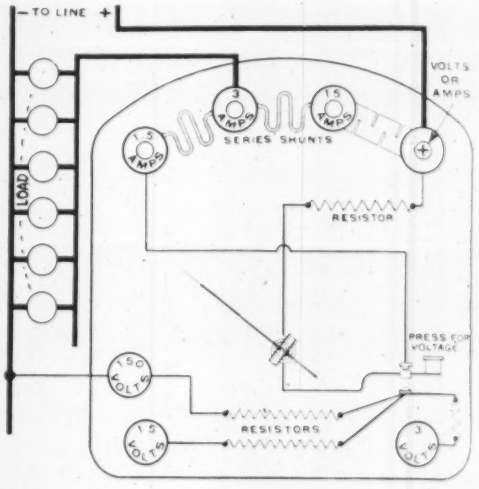

Fig. 33-10. Internal diagram of the Weston "Model 280" portable d.c. volt-ammeter.

curacy and efficiency is necessarily sacrificed; but instruments where extreme flexibility and portability rather than precision of measurement and the need of observing several magnitudes simultaneously, are the dominating considerations, have a wide application. In general it may be said that the greater the number of ranges to such an instrument, the greater the possibility of accident in its use; and that when the movement is once burned out or subjected to mechanical damage, not only one instrument but the whole group represented is disabled. Wherever possible combination volt-ammeters should be avoided and separate instruments provided for measuring the several magnitudes.

Care should be taken to distinguish among four instrument definitions which are sometimes confused:

Voltameter (Coulometer): An electrolytic cell arranged for the measurement of a quantity of electricity by the chemical action produced. (A.I.E.E. Standard Definition.)

Volt-ampere meter: An instrument for measuring the volt-amperes in an alternating current circuit.*

Voltmeter-ammeter: An instrument combining a voltmeter and an ammeter movement electrically separate but in a single case.*

Volt-ammeter: A multiple purpose instrument in which both volts and amperes may be alternatively measured by a single movement according to the method of connection to the circuit.*

*Not officially accepted definitions, but generally considered as good usage.

7. Connecting Ammeters and Voltmeters

It is obvious that in connecting ammeters and voltmeters to a circuit the ammeter is placed in series with the line in which current is to be measured, while the voltmeter is connected across the circuit. If the ammeter is intended for use with a shunt, it is of course essential that the shunt be placed directly in series with the line. The ammeter with its leads may then be left in circuit or removed as desired, without disturbing the continuity of the circuit. In the use of a voltmeter care must be exercised that any external resistor intended for use with the instrument be placed in series with it before the instrument is connected to the line. When such an instrument is disconnected from the line, even temporarily, it is desirable that the resistor or multiplier also be removed from the circuit.

Where current or voltage transformers are used with ammeters or voltmeters, each transformer with the associated secondary leads and the instrument supplied therefrom may be treated as an individual instrument and

connected in circuit accordingly, the current transformers in series with, and the voltage transformers across, the circuit under test. Typical connections are shown in Figs. 33-11 and 33-12. The standard secondary current value for a current transformer is usually 5 amperes, and the secondary voltage value for a voltage transformer may be 100, 110 or 115 volts, the latter value agreeing with the most recently adopted standards. When the indication obtained with a certain combination of instrument transformer and instrument is low on the scale, it is not good practice to use an instrument of a lower range, particularly in the case of current measurement. It is better to select transformers having a rating suited to the range of magnitudes to be measured.

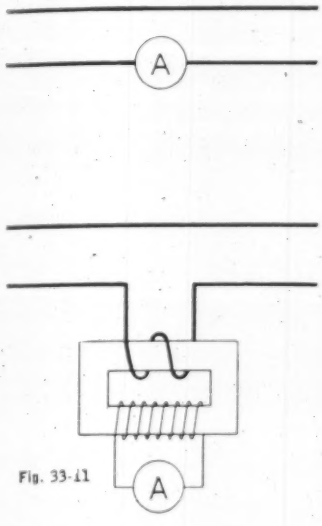

Fig. 33-11

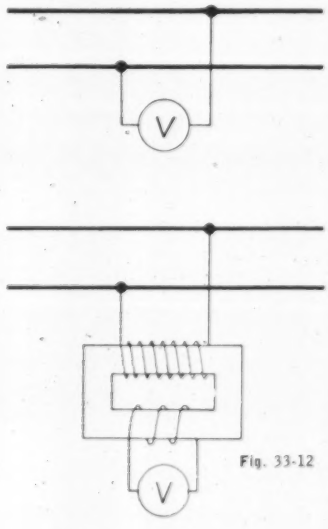

Fig. 33-12

Mutual Effects

When an ammeter and a voltmeter are simultaneously connected to the circuit it is to be remembered that each instrument may to a slight degree affect the reading of the other. If the voltmeter is tapped on the "line" side of the ammeter it will read a voltage higher than that applied to the load, due to the drop in the circuit of the ammeter. On the other hand, if the voltmeter is connected on the "load" side of the ammeter, the current which it draws will be included in the reading of the latter, tending to give an indication slightly higher than the true value. With direct-current instruments the errors so introduced are generally small and need be considered only where very small amounts of power are involved or where precision is required. In alternating-current measurements greater attention must be paid to these sources of error, because the power consumptions of the instruments are much larger than those of d'Arsonval movements, and the currents drawn by the instruments may not be in phase with the load current. These sources of error are more fully discussed in a subsequent chapter.

8. Springs

Since the whole control force in most of the indicating instruments here considered is furnished by the spring or springs, it is obvious that these must be chosen and designed to have great permanency of characteristics. Not only must they retain for years their calibration elasticity under all service conditions, but possible effects of temperature are aggravated in those types of movements wherein the springs are called upon not only to furnish the control torque but to carry current to moving parts. Fortunately the passage of an electric current through the metal of a spring has no appreciable direct effect upon its elastic characteristics. In general high elasticity does not accompany high conductivity (witness the ductility of pure silver) so that appreciable resistance, with consequent temperature rise upon passage of a current, is likely to be encountered; and a careful compromise between elasticity and conductivity is the task of the designer. In instruments of the permanent-magnet type, where relatively little power is carried into the moving coil, the problem is not so great as in electrodynamic movements, where an appreciable current must be transmitted. In voltmeters, where a rather high resistance is not only permissible but desirable, the problem is not serious; but in ammeter (millivoltmeter) design these points must be given careful consideration. In some of the heavier types of movements, and particularly in direct-recording instruments, it frequently is found desirable to confine the function of the

MANUFACTURERS' NEW LITERATURE

In this department we each month list the printed matter issued by manufacturers. Unless otherwise noted, any of the items listed may be secured free upon application to the issuing firm. Manufacturers who have not yet sent in their printed matter are invited to do so.

B139 **Glass Electrode for pH Measurements.** Leaflet F-160, 4 pages. Description of glass electrode. Leeds & Northrup Co., 4901 Stenton Ave., Philadelphia, Pa.

B140 **Amateur Microscope.** Two leaflets 1-36 and 1-39 illustrate the new Gem microscope. Bausch & Lomb Optical Co., Rochester, N. Y.

B141 **Chromalox Electric Heating Units.** Bulletin CA-106 briefly describes the following types: strip heaters, space heaters, ring units, immersion heaters and finstrip. Edwin L. Wiegand Co., Pittsburgh, Pa.

B142 **Gummed Tape Tester.** Four page leaflet describes the improved McLaurin gummed tape tester for determining the adhesive quality of glue when applied to tapes. Thwing Instrument Co., 3339 Lancaster Ave., Philadelphia, Pa.

B143 **Paper Hygroscope.** Sales Bulletin No. 1 describes a sword hygroscope for determining moisture content of paper in the pile. Lithographic Technical Foundation, Inc., 220 E. 42nd St., New York, N. Y.

B144 **Tachometer.** Small leaflet gives data on new six range hand tachometer. Foxboro Co., Foxboro, Mass.

B145 **Self-Acting Temperature Regulator.** Catalog 36R gives the details of regulator as well as data on accessories. Taylor Instrument Cos., Rochester, N. Y.

B146 **Grits and Grinds.** The Jan.-Feb. issue contains articles on safety stair treads, abrasive papers and cloth, and polishing and buffing. Norton Co., Worcester, Mass.

B147 **Tuckerman Optical Strain Gage.** Bulletin describes the gage for precise measurement of tension and compression strains in hot and cold metal specimens, brick, concrete, etc. American Instrument Co., Inc., 774 Girard St., Washington, D. C.

B148 **Chromalox Electric Air Heaters.** Bulletin C-108 illustrates various models for heating hard to heat places. Edwin L. Wiegand Co., Pittsburgh, Pa.

B149 **Fulscope Recording Regulators.** An 8-page descriptive bulletin shows the details of this new regulator with the "Universal Sensitivity Adjuster." The bulletin contains an illustration of the 64 regulators on the temperature control panel board of the National Broadcasting Company Studios in the R.C.A. Bldg. Taylor Instrument Cos., Rochester, N. Y.

B150 **Turbidimeter.** Leaflet describes the Wagner turbidimeter for measuring the fineness of sub-sieve sizes of cement and other finely divided materials. E. E. W. Bowen, Bethesda, Md.

B151 **Pyrometer Checking Set.** Bulletin 16-1 illustrates the Treasure Chest, a portable, checking potentiometer for checking all types and makes of pyrometers. Thwing Instrument Co., 3339 Lancaster Ave., Philadelphia, Pa.

B152 **Manometer.** Leaflet illustrates the Jensen U-tube manometer. Jensen Instrument Co., 624 East 4th St., Los Angeles, Calif.

B153 **Radiation Pyrometers.** Bulletin 11 is a revision of the earlier bulletin and shows the water jacketed type receiving tube. Thwing Instrument Co., 3339 Lancaster Ave., Philadelphia, Pa.

B154 **Chromalox Electric Unit Heaters.** Bulletin C-118 illustrates the blower type unit heaters for auxiliary heating. Edwin L. Wiegand Co., Pittsburgh, Pa.

B155 **Flow and Liquid Level Regulators.** 8-page attractively printed bulletin contains details on regulators and recorders for flow and liquid level. Taylor Instrument Cos., Rochester, N. Y.

B156 **Recording Densitometer.** Bulletin 571 describes the Weigle Recording Densitometer built by Société Genevoise d'Instruments de Physique and sold in the U.S.A. by R. Y. Ferner Co., Investment Bldg., Washington, D. C.

B157 **Electrical Time Delay Relay.** Bulletin N-1 discusses the operation and specifications of the Agastat. American Gas Accumulator Co., Elizabeth, N. J.

B158 **Step-Voltage Regulators.** 8-page bulletin illustrates and describes the type U-R regulators. Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa.

B159 **Predetermined Electric Counters.** Bulletin lists 10 models of selective predetermined electric counters with pilot or control circuits, preselective switches, automatic resets and signal circuits for accurate production counting and control. Production Instrument Co., 1315 South Wabash Ave., Chicago, Ill.

B160 **Chromalox Electric Cartridge Units.** Bulletin C-113 shows various type cartridge units with construction details. Edwin L. Wiegand Co., Pittsburgh, Pa.

B161 **Dubl-Response Regulator.** Catalogue 37R lists the advantages of this type regulator. Taylor Instrument Cos., Rochester, N. Y.

B162 **Capacitors.** Catalogue GEA-77F gives complete and detailed information on pyranol-treated capacitors. 28 pages. General Electric Company, Schenectady, N. Y.

B163 **Sperry Detector.** This issue of the Sperry house organ gives charts and graphs of rail testing during past 4 years. Sperry Gyroscope Company, Sperry Bldg., Brooklyn, N. Y.

B164 **Lathes.** Catalogue 94 is a 72 page book showing the 1934 models of South Bend lathes and attachments. South Bend Lathe Works, 425 East Madison St., South Bend, Ind.

B165 **Small Electric Furnaces.** Leaflet briefly describes furnaces built with a new heating element "Doreco." Cooley Electric Furnace Company, 433 North Capitol Ave., Indianapolis, Ind.

B166 **Industrial Dial Scales.** Condensed Catalog No. 7 shows the Kron construction as well as photographs of the various models and below each illustration the data as to size, beam capacity, etc. Kron Company, Bridgeport, Conn.

B167 **Binoculars.** Beautifully printed 40-page booklet which is really a manual of information about binoculars. It contains information on the various B&L binoculars. Bausch & Lomb Optical Company, Rochester, N. Y.

B168 **Rheostats.** Catalog 1370 is a 12-page bulletin and gives detailed data on the various "Jagabi" rheostats, resistance units, non-inductive rheostats, how to select a rheostat, etc. James G. Biddle Co., 1211 Arch St., Philadelphia, Pa.

B169 **Humidistat.** Bulletin No. A, 4 pages, illustrates the Friez humidistat, an automatic humidity control for air conditioning. Julien P. Friez & Sons, Inc., Baltimore, Md.

B170 **Precision Bore Tubing.** Leaflet 4548E gives data on precision bore tubing manufactured by the Jena Glass Works, Schott & Gen. Exclusive U. A. agents Fish-Schurman Corp., 230 East 45th St., New York, N. Y.

B171 **Meter Accessories.** Form 429 lists graphic meter ink, cable clamps, meter carrying cases, meter shipping cases, chart inspectors, current transformers, connectors and pen filler. Esterline-Angus Co., Indianapolis, Ind.

INSTRUMENTS, 330 W. 42nd St.
New York City

Please have me supplied with a copy of each piece of Manufacturers' Literature listed below.

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Name.....

Position.....

Firm.....

Street and No.....

City.....State.....

control spring solely to furnishing counter-torque, and to carry the current into the movement by small high-conductivity spiral filaments (usually of silver) exerting a negligible mechanical turning moment on the moving element.

The most common material for instrument springs is phosphor bronze, though were it not for the magnetic characteristic there would be many applications where steel would be preferable. The winding and tempering of instrument springs is a highly specialized class of work; and new methods of carrying this out are continually being devised. The best instrument springs yet available leave much to be desired; and it is hoped that there will yet be developed a non-magnetic alloy wherein the desired characteristics of elasticity, permanency and conductivity will be combined to a higher degree than at present.

In the handling of instrument springs the greatest care must be exercised. A relatively small heat effect may alter the elastic properties, making soldering undesirable; and slight corrosion, either from soldering flux, or even from handling with bare fingers, may affect the outside fibres of the metal, which, of course, are exposed to the greater stresses in operation. Some makers therefore gold-plate their springs, but it is said by some authorities that the requisite operations cannot be performed without abuse. Prolonged extreme deflection tends to be followed by creep observable as a temporary zero shift. Kinking (and for that matter all localized stresses) produces errors appearing as exaggerated creep and corresponding zero shift. When adjacent turns of the coil touch or hook on to each other, the result is a calibration curve differing widely on increasing values and decreasing values. For up-to-date detailed information on instrument springs the reader will do well to consult Carson's recent and forthcoming papers.*

*R. W. Carson. "Better Instrument Springs." *Electrical Engineering*, Vol. 53, Feb. 1934, pages 282-286.

R. W. Carson. "Hooke's Law Amended" and "Bibliography on Instrument Springs." (Both reprinted in one pamphlet) Instruments Publishing Co., New York, 1934. [Not yet issued at this writing.]

"The hell with it!"

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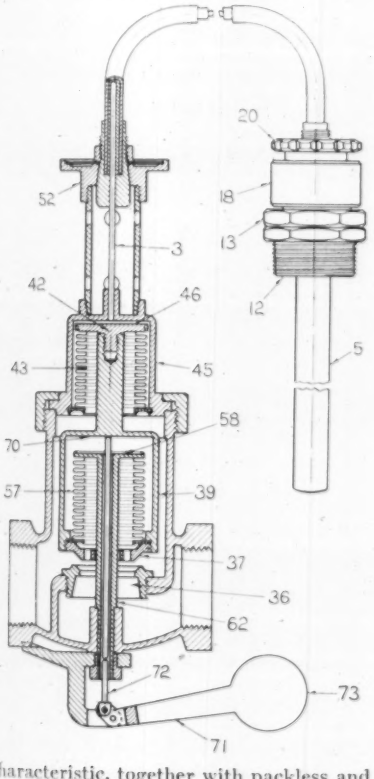
NEW INSTRUMENTS

Write Information Section, Instruments Publishing Company, for additional information.

New Type of Self-operating Temperature Controller

Emil T. Johnson Regulator Co.

IN outward appearance this new temperature controller for steam-heated applications resembles conventional type "self-ops" but it differs from these sufficiently to constitute a new type. The conventional type as usually built requires >10°F. drop at bulb to move valve disk from wide-open to closed against steam pressure; this new type, it is said, only requires <1°F. and "special regulators have been made that operate on <½°F. variation." It is furthermore claimed that whereas in the conventional type the power to operate the throttle is entirely derived from the bulb, this new type requires <1% of such power from the bulb, the other 99+ % being "obtained from the heat energy of the steam in the valve body." It is said that this



characteristic, together with packless and "100% balanced" valve construction, makes this new regulator "unbelievably sensitive." The new principle employed is the transfer of a small portion of volatile liquid from a "colder" to a "warmer" space (or vice versa) in the valve end of the system.

Construction. Valve body is made of bronze; other parts of brass or other non-corroding materials. Valve disk 37 and seat ring 36 including central guide stem 62 are made of Monel Metal and NT 4 alloy. The balancing means include two flexible metal bellows, 43 and 57, of same effective area, equal to or larger than opening in seat ring 36. With valve open or closed, pressure inside valve body against movable wall 42 is balanced by pressure against effective area of wall 70 on casing 39, the inside of which is exposed to atmosphere through hole in guide stem 62. Valve disk 37 being perforated to allow steam to circulate freely inside bellows 57 and against stationary wall 58, no additional unbalanced area is exposed to steam pressure when valve is open. Valve disk is free to float laterally and is guided by guide stem 62. "This makes an almost frictionless construction with a perfect seating." Bellows 43 and casing 45 form a vaporizing chamber connected to bulb 5 through capillary tubing 3. Bulb 5 and tubing 3 are normally filled with a suitable liquid while at the same time a partial vacuum exists in chamber 46.

Operation: A variation of 1°F. will move the liquid inside the capillary tubing >14", so that a slight variation in temperature of bulb 5 will move the liquid from the relative cool part on one side of flange 52, to the vaporizing temperature inside chamber 46 where it will flash into vapor and expand >500 times and close the valve. The action, whether on the opening or closing stroke, is instantaneous. As an excess of liquid in chamber 46 will do no harm, this regulator "will stand >100° overload without injury." Valve is held open by atmospheric pressure working against wall 70 and also by spring tension in double ply bellows 43 and 57. The loss in efficiency due to the work of compressing these bellows is said to be reduced to nothing by the action of bell crank lever 71. This lever is so arranged that the pressure against pin 72 and movable wall 70, due to its weight and lever ratio, is at its maximum when the valve is open and consequently the spring tensions of both bellows are at minimum. When valve is closed and tensions in both bellows are at maximum, weights 73 on bell crank lever 71 have swung up to a vertical position, reducing the lever ratio to such an extent that "it fully compensates for the increase in spring tension of the bellows."

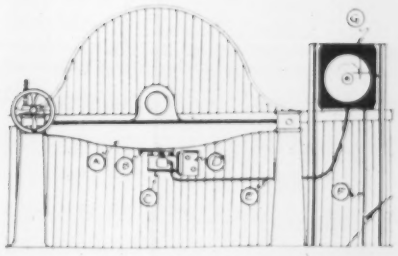
Adjustments. This regulator has a range of 40°F. and is set for the desired temperature by loosening locknut 20 and turning adjusting nut 18. Turning nut 18 changes the volume of the thermostat end by moving a plunger which is sealed to bulb 5 by means of a flexible brass bellows. One-sixth of a revolution of adjusting nut 18 will open or close the steam valve. It is said that the regulator can be adjusted "over its complete range in 10 seconds by turning said nut by hand."

Special Piston Type: When large valves and high pressure are required, and when chamber 46 is not used as a vaporizing chamber, which makes a hermetically sealed system essential, pistons may be used instead of bellows 43 and 57. In such a construction, the lower piston has a floating connection with guide stem 62, to allow valve disk to seat properly.

Thickness Recorder

Thwing Instrument Co.

THOUGH designed especially for the paper industry as a beater roll recorder, this new instrument is reported to function so reliably that it should find applications in other industries. It simply consists of an auto-

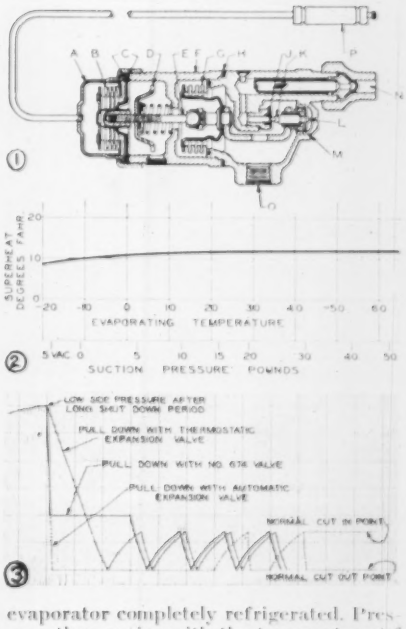


transformer *C* connected to 12" recording voltmeter *G* by 3-conductor cable *E*; and of iron plate *B* (bolted to lighter bar *A* or to whatever part is to have its vertical movements recorded). *D* is the transformer support and *F* is the connection to 110-volt a.c. supply. *Operation*: Movements of *A* are translated into variations of magnetic flux, hence into variations of voltage. Sensitivity is such that 0.00025" displacements are recorded. Variations in a.-c. line voltage cause no errors.

Thermostatic Expansion Valve

Detroit Lubricator Co.

FOR domestic refrigerators and other factory-assembled products, the new "No. 674" is the well-known "No. 673" modified into a single-purpose valve having only one spring. Instead of maintaining constant pressure it keeps the

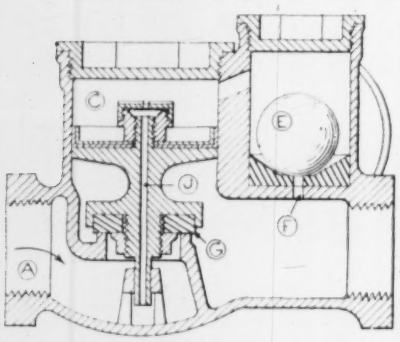


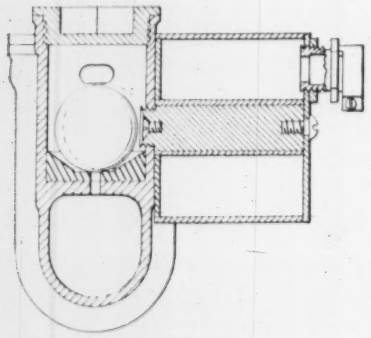
evaporator completely refrigerated. Pressure then varies with the temperature of the evaporator exactly as with a flooded type evaporator. *Principle* (see Fig. 1): Bellows *B* responds to temperature in bulb *P* and opposes expansion valve bellows *G* which responds to low side pressure and tends to close valve on increasing pressure. Reaction of two bellows thus causes valve to operate on differential so that, for example, when bulb is clamped to suction line the valve controls the superheat at that point (see characteristic curve, Fig. 2) over a wide range of pressures. The pull down characteristic, due to gas-filled bulb *P*, is graphed in Fig. 3 (heavy line) as compared with that of the liquid charged thermostatic expansion valve No. 373 (light line).

Electro-hydraulic Valve

A. F. Hoppe Engineering Co.

NO stuffing box, gaskets, springs or levers are employed in this new electrically operated valve announced in sizes from ¼" to 1" and in



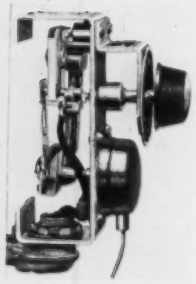


five pressure ranges: 10-25, 25-65, 65-85, 85-150 and 150-200 lbs./in.². Energy consumption when current is on is 16 watts from any a.-c. or d.-c. supply. Normally open, or normally closed as in design illustrated, the operation of which is as follows: *To open*—Solenoid being energized, ball E is rolled off port F, relieving pressure in C. By-pass J being smaller than F, differential lifts piston. *To close*—Ball seats itself, closing F. Pressure builds up in C through J, forcing piston down. *Media*: ammonia, brine, CO_2, oil, steam, etc. When required, valves can be furnished to function buried underground or submerged in water.

Cabinet Thermostat

Detroit Lubricator Co.

FOR enclosure or forced circulation type heating, cooling and air-conditioning units, the new No. 261 Cabinet Thermostat can be used to control heating elements, solenoid or electric valves, fans, etc. It has the advantage of being installed completely inside the cabinet except for the exposed dial-and-knob adjustment. It may be mounted at a convenient location and correctly wired at the time of assembly or at the factory.

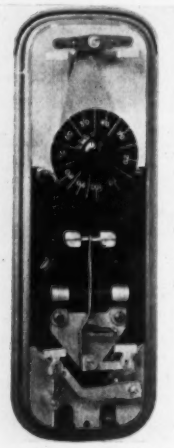


With some units, complete factory assembly is possible, eliminating wall thermostats and the consequent need of installing wiring in BX or rigid conduit. Considerable installation cost is thereby saved. The No. 261 is of the high-voltage type: no need of transformers or relays up to 1 h.p. single-phase 110 or 220 volt a.c. or ½ h.p. on 110 or 220 volt d.c. Standard adjustment ranges: for heating, 45-80°F.; for cooling, 75-90°F. Supplied only in single-pole single-throw type to make or to break.

Humidistats and Thermostats

Julien P. Friez & Sons, Inc.

ROTARY knob-and-dial type of setting, and modernistic appearance, are outwardly visible features of these new models. Inwardly they represent the culmination of the successive improvements described in *Instruments*, Feb. 1933, page 39, and May 1933, page 109. Illustration shows new model humidistat with cover removed. Among available contact arrangements are the following: *Type H-4*—Snap acting, single pole, single throw (2-wire), to complete circuit at low. Suitable for use with humidifying equipment and for operation of solenoid valves, thermal type valves and damper motors, or for 2-wire booster relays where heavy loads have to be handled. *Type H-5*—Snap acting, single pole, single throw, 2-wire, to complete circuit at high. Suitable for same uses as H-4. *Type H-6*—Snap acting, single pole, double throw (3-wire). As used for positive type motor valves or damper motors. Also *Type H-7*—Same as H-6 but without snap action. As used for 3-wire system holding-circuit type relay-transformer sets, or reversing type motor valves only. New model thermostats have corresponding contact arrangements. *Primary elements* of humidistats are multiple human hair; of thermostats, bimetallic. Contacts are pure silver, rated for 110 volts a.c. or d.c., 25 watts. Both classes of instruments now come in aluminum cases with the new "Alumilite" anodic finish.



Float-thermostatic Trap

Sarco Co., Inc.

TYPE FTO-H, latest addition to the Sarco line, carries the working pressure now available to 180 lbs./in.². It is said to be compact in design and light in weight so that it can be supported directly on the piping. Inlet and outlet are on the same side, a small vertical distance apart for easy connection to horizontal pipes. All working parts are on the cover and readily exposed for cleaning without disturbing the connections. The automatic air bypass, arranged on the down-board side of the trap so that the thermostatic element is at no time exposed to the full steam pressure, keeps the trap vented so that it cannot become air-bound. Main discharge valve and seat are of stainless steel.

Rate of Flow Indicator

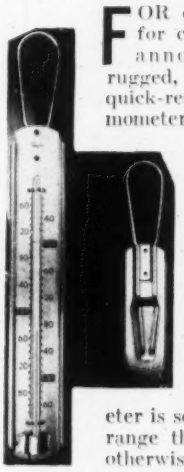
Jensen Instrument Co.

SAID to be "the oldest and latest" manometer, this new instrument consists of a U-tube of industrial construction but provided with a novel adjustable scale, the zero of which can be made to coincide with the lower of the two levels of manometric liquid. This "patent revolving scale" is moved by turning the thumbscrew at the upper right. Two models are announced: a wall type 21¼"x4¼"x1½" and a panel type 21¼"x6"x1½" (⅛" flush), each weighing 11 lbs. and built to withstand 15 lbs./in.² w.p. The white borosilicate glass tubes are standard ½"x18" packed at each end with oil-proof rings and steel glands and nuts. At bottom of each glass is a ball check to prevent "blow-over" in case of over-range, consisting of stainless steel seat, ball and ball retainer. A pulsation damper cock is conveniently located. *Primary elements, etc.* (made by leading manufacturers) include orifices, Venturi throats, Pitot tubes, as well as seals, traps, etc. Coefficients being known, scales reading flow units are laid out which are accurate to 0.01" linear, therefore within error of observation, but it is said that users prefer scales graduated up to square roots of 144, 121 or 100" water differential, so that they may use any desired coefficient, and simply change coefficients when flow characteristics are changed.

Confectioners' Thermometer

Taylor Instrument Companies

FOR deep-frying as well as for candy making, there is announced an especially rugged, easy-to-clean and quick-reading mercury thermometer. All metal parts are solid copper, copper-riveted and of a new design which makes for strength and for maximum protection of the thoroughly annealed glass tube. Clamp at back of case permits fastening to side of kettle. Size: 12½" case, 16½" overall. Candy range thermometer is scaled 50-370°F., frying range thermometer 60-500°F.; otherwise, they are alike.



800-amp. "Tong Test"

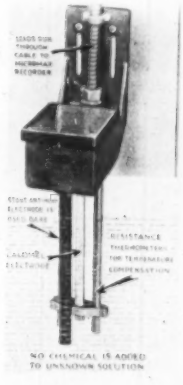
Columbia Elec. Mfg. Co.

THE original 400-amp. model of this ammeter was announced in *Instruments*, Feb. 1933, page 41. It has a hinged magnetic circuit, permitting it to encircle a conductor to read current without interrupting service. New models are now announced for reading up to 800 amps. but instead of being suitable for *both* a.c. or d.c. they are suitable for *either*. Neither current transformers nor shunts are required.

Industrial pH Electrodes

Leeds & Northrup Co.

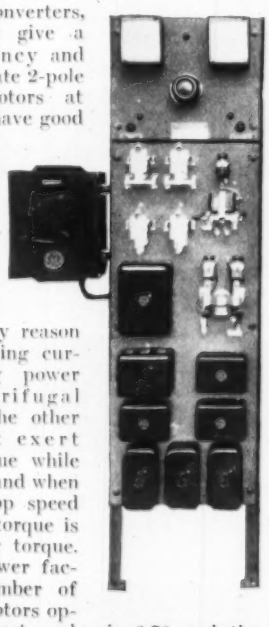
USED absolutely bare, this new antimony electrode which never requires platinizing is designed for severe industrial service such as continuous pH indications (or records) of paper stock in board mills and of alkaline treated water. No sampling line is needed, for it dips directly into the solution. Illustration brings out some features suggesting new fields of pH measurement and control in the process industries. Mounting the cell is so simple a matter that in almost every application it may be tried out in a number of places to determine the optimum location where pH is most directly related to the process or product control involved. It can be used in solutions containing relatively large amounts of suspended matter. Solution temperature variations are automatically compensated for. Immersion should remain complete, of course; but in connection with processes where liquid level must vary, suitable float-supports may be rigged up. These new cells are designed to be used with the maker's line of "Micromax" potentiometric indicators, recorders and automatic controllers (*Instruments*, September 1931, page 505, March 1933, page 63).


LEADS RUN THROUGH CABLE TO MICROMAX RECORDER
GLASS ANTIMONY ELECTRODE IN PIPE GLAND
RESISTANCE THERMOMETER FOR TEMPERATURE COMPENSATION
CALOMEL ELECTRODE
SOLUTION
NO CHEMICAL IS ADDED TO UNKNOWN SOLUTION

Special Motor Control

General Electric Co.

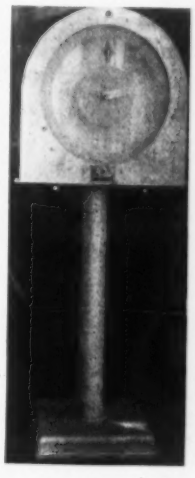
THIS novel application of the induction frequency converter permits the use of special motors (example described is for driving sugar centrifugal extractors). Induction frequency converters, employed to give a high frequency and thereby operate 2-pole induction motors at high speeds, have good voltage regulation while motors are running loaded at top speed but lack ability to accelerate motors even at no load, by reason of high starting current at low power factor. Centrifugal motors, on the other hand, must exert greatest torque while accelerating, and when they reach top speed the required torque is <0.1 starting torque. The mean power factor of a number of centrifugal motors operating on short cycles is 0.70 and the wattless component must be supplied from the line, including the magnetizing current of the converter. A synchronous driving motor for the converter can be designed to supply this wattless current, thus raising the power factor of the total load to any desired value. Illustration shows control panel of a recent example: a 70-kw. 0.70-pf. converter set driven by a 50 h.p. synchronous motor, to transform power from 3-phase, 25-cycle, 550-volt system to 3-phase power at 58.3 cycles, 428 volts for operation of six 30 h.p. motors.



Sheet Measuring Device

The Clark Controller Co.

FOR use in sheet or tin mills using automatic roller and catching tables, this new instrument can be applied to existing installations without modifying them. After sheet passes through rolls it automatically gives an indication of its own length by movement of pointer on an illuminated dial which may be calibrated to read directly in inches. Position of pointer is maintained while sheet is taken back over top of rolls and until it starts through next pass, giving operator time to note the length and set his rolls accordingly. During next pass pointer moves from previous position to new position, again indicating length of sheet after latest pass. This operation is repeated until required length of sheet is obtained. Then, next piece delivered from furnace automatically resets pointer.



Lock-out Push Button

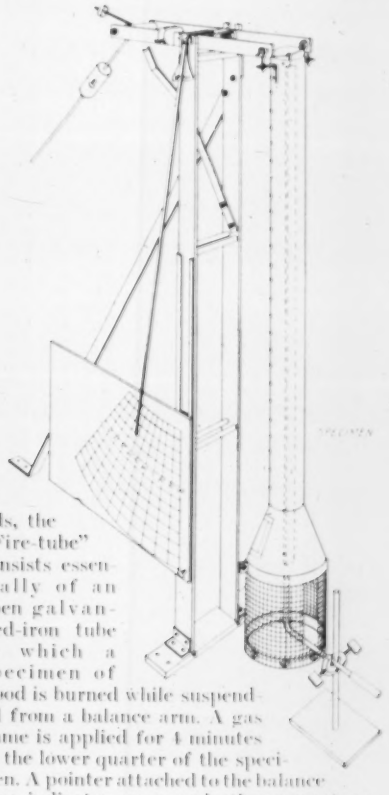
The Electric Controller & Mfg. Co.

FOR use in connection with the remote control of automatic motor starters, there is announced the new EC&M 270-A Type J Form C Vapor-proof and Dust-tight, Safety Lock-out Push Button. It is for 3-wire low voltage protection installations where it is desired to start and stop a motor through its magnetically-operated starter or controller from two or more push button control stations, at *any* one of which it may be desired to lock the push button in the "off" position to prevent operation of the motor-driven machine. Where push button stations are located on different floors or obscured from view of the main push button station adjacent to machine, the insertion of a padlock on the "stop" side of any of these new push buttons will prevent operation of the machine until the authorized person has removed the padlock and re-established the control circuit. In addition, this push button is especially suited for dusty or gaseous locations.

Inflammability Tester

Forest Products Laboratory

DEVELOPED by M. E. Dunlap, Forest Products Laboratory engineer, to overcome some of the limitations of the numerous older test methods, the "Fire-tube" consists essentially of an open galvanized-iron tube in which a specimen of wood is burned while suspended from a balance arm. A gas flame is applied for 4 minutes to the lower quarter of the specimen. A pointer attached to the balance arm indicates on a scale the percentage loss in weight as the burning proceeds. The temperature at the top of the tube is measured by a thermoelectric pyrometer. Wood decomposed by the flame in the form of coals is caught on wire mesh at the bottom of the tube, their tendency to glow being noted by the operator. The ignition flame is controlled so as to give a temperature of 1832° ± 45°F. (1000° ± 25°C.), measured with a No. 14 A. W. G. thermocouple, at the hottest part of the flame, and 356° ± 9°F. (180° ± 5°C.) at a point 1" above the center of the tube without a specimen in place. These conditions are obtained with a Bunsen burner, adjusted to give an 11" blue flame with a tall, indistinct, inner cone. The fire-tube is about 50" long over all. The specimen, about 40"x1"x½", is suspended with its lower end 1" above the top of the burner. It thus is exposed to temperatures ranging from those existing under severe fire conditions down to approximately the ignition point of wood.



ASSMAN
Aspiration Psychrometer
for precise determination of the actual Temperature and Humidity of Air
R. FUESS, INC. **NEW YORK**
ESTAB. 1865 245 WEST 55th ST.

Polarizing Microscope

By E. W. Melson*

IN this new instrument previous improvements achieved by B. & L. are incorporated. Such faults as shift of focus, astigmatism, and change of magnification, which resulted when the tube analyzer was inserted in the old instruments, have been corrected. The stand of the new LC has adequate balance and stability, the curved arm permitting abundant working space at the stage. The V-shaped base with its long heel gives stability in

inclined positions. The 125 mm. circular stage reads directly to 1° and is equipped with a vernier reading to 3'. The substage, focusable by diagonal rack and pinion, carries the polarizer and condenser. Special attention was paid to securing clearance at the stage, and vertical clearance so that the microscope can be used with the Emmond's Universal Stage, the increasing importance of which makes this a highly desirable feature. The new LC Model has a 39 mm. body tube of nearly uniform size from the nosepiece to the large diameter eyepiece. Directly above the nosepiece is a slot for introducing accessories, such as the quartz wedge, rec of the first order, quarter wave plate, etc. Above this is the stigmatic tube analyzer and the Bertran lens with iris diaphragm. Unusually fine focusing adjustment has been achieved, the screw pitch having been changed so that each graduation on the drum is equivalent to 2 microns of movement. Depth and thickness measurements are thus greatly simplified. The rack is much longer than usual, providing for the regular coarse adjustment and yet allowing clearance for the Universal Stage. Unusual steadiness is thus achieved for the body tube in relation to the specimen. The new, quick-changing, centerable nosepiece of the LC Microscope is highly advantageous in its ability to center, and keep centered, its objective. Eyepieces, of large diameter with exceptionally large fields, are equipped with cross hairs and focusing eye lenses. An adapter for taking the Universal Holder, Positive Eyepiece, and accessories, is supplied with each microscope. Ordinary eyepieces or micrometer eyepieces may thus be used. The substage of the new model has been designed for equipment with either a condenser of 1.10 N.A. or an achromatic condenser of 1.40 N.A., each interchangeable. The 1.10 condenser has an eccentric shutter for facilitating refractive index measurements with oblique illumination. Both condensers are on sliding mounts. They are equipped with an iris diaphragm and provided with a means for swinging out the upper lens to illuminate the larger field required when working with the 16 mm. objective. The mirror can be swung off the optical axis for obtaining oblique illumination. Its fork mount slides vertically on the mirror bar. The polarizer, a Glan Thompson prism in rotatable mounting fitted with an iris diaphragm, is graduated in 15° intervals, can be rotated 360° and has a detent to locate it at 0° position. The Stigmatic Tube Analyzer is an Ahrens prism which slides between the stigmatizing lenses and is rotatable through 90°, graduated in 5° intervals. The stigmatizing lenses are not carried on the Ahrens prism mount, but are fixed permanently in the body tube so that neither change in magnification nor change in focus is required when introducing or removing the analyzer.

*Bausch & Lomb Optical Co.

Acree pH Meter

American Instrument Co.

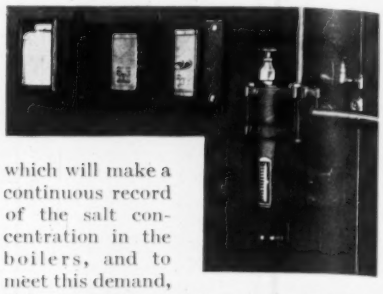
FOR field, factory or laboratory work, the Acree Universal pH Meter is adapted to use with glass, hydrogen, quinhydrone, or antimony electrode, and with any type of solution, including colored, very dilute, weakly buffered, oxidizing or reducing, and colloidal solutions. A null method of measurement makes the accuracy independent of the e.m.f. of the enclosed dry cell. Except in the case of the glass electrode, with

which a sensitive galvanometer must be used, the instrument is entirely self-contained, and the single panel meter is used both for balancing and reading. Two models are available, one with an accuracy of ±1 mv. on the 0-500 mv. scale and ± 2mv. on the 0-1000 mv. scale, and one with an accuracy of ±0.5 mv. and ±1 mv.

Boiler Concentration Recorder

Esterline-Angus Co.

IN order to better the economy of operation of large boilers and to protect the blading of turbines, there has been a demand, it is said, for an instrument



which will make a continuous record of the salt concentration in the boilers, and to meet this demand, this new instrument was developed. It consists of two units: The *pressure reducing chamber* is a cast iron chamber fitted with an adjustable inlet needle valve, an electrode, and an indicating thermometer. Boiler water pressure is reduced to atmospheric, the upper part of the chamber having a free opening. An overflow, which keeps the chamber partly filled and the electrode completely immersed, is piped to the boiler feed supply so that no water is lost. By reducing the pressure to atmosphere a practically constant temperature of 212°F. is maintained, eliminating errors and making compensating devices unnecessary.

The *recorder* is a standard Esterline-Angus graphic ohmmeter connected to a 110 or 220 volt a.c. circuit and to the electrode, so as to record the resistance of a fixed column of water from the boiler, which is a function of the percentage of any salt held in solution. It can be furnished in either portable, wall, and front or flush switchboard cases, with either spring driven or synchronous motor chart drive. Charts are 90 feet long, 6" wide, and have a range of 0-3000 ohms. The measuring element is of the electrodynamic type in which no iron is used. The writing mechanism is the one used in all Esterline-Angus recorders. The instrument as a whole is built to withstand the application of a breakdown test of 2500 volts a.c. for 1 minute.

Differential Speed Indicator

General Electric Co.

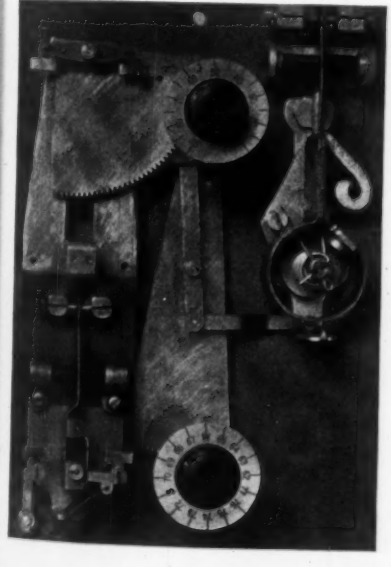
INDICATING the percent difference in speed between two rotating shafts, this device was especially developed for use in steel mills where it is desired to determine the draft or reduction in thickness of material during the rolling-down process in cold-strip mills. It consists of two identical a.-c. generators having linear excitation characteristics, and a ratio-type instrument. The output from one generator is connected to one coil of the instrument and the output from the second generator to the other coil of the instrument. The fields of the generators are connected in series and hence are always working at approximately the same field strength. In this manner, the voltages generated by either generator at the same speed are equal, and at any other speed are proportional, to the speed of the generator. The coils in the instrument are identical and hence have the same impedance so that the instrument, by indicating the ratio of the currents,

shows the percent difference in speed. This "Draft Gauge" will indicate up to 60% draft over a 10-to-1 speed range and at a minimum speed range of 250 r.p.m. Generator field control maintains approx. uniform generated voltage over the entire speed range to prevent excessive current at high speeds.

The "Comfortrol"

Julien P. Friez & Sons, Inc.

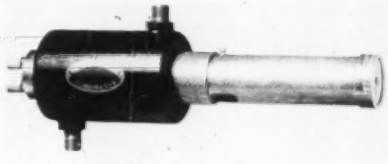
IT is neither temperature nor humidity but a combination of the two that results in a given body sensitive condition, termed "Effective Temperature." See *Instruments*, Sept. 1930, pages 560-563 for charts showing that it is "Effective Temperature" and not ordinary dry-bulb temperature, nor "relative" humidity, which need control by air-conditioning equipment. The Friez Comfortrol is now announced as the first automatic control instrument giving Effective Temperature or true human comfort conditions. It takes the place of both thermostat and humidistat, giving better results and being suitable for use with all types of air conditioning equipment up to the most elaborate winter-summer 100% air conditioning plant. It is not, of course, to be expected that the simpler conditioners will give all-year-round results equal to those possible with elaborate plants by the mere addition of a Friez Comfortrol, but it is contended that this new automatic control will assure the best condition of human comfort that can be obtained from any given air conditioner. The Friez Comfortrol embodies a temperature sensitive element and a relative humidity sensitive element with their complementary electric-contact mechanism and setting pointers so interlinked that it is possible not only to vary the ratio of the two factors of temperature and humidity going to make up Effective Temperature in any desired proportion, while leaving the Effective Temperature unchanged; but which also provides separate means of varying that Effective Temperature as may be desired. Two knurled knobs and calibrated dials are provided. The upper one determines the relative humidity setting while simultaneously correcting the dry-bulb temperature in the correct ratio to insure that effective or body sensitive temperature is not altered. The lower dial is the one whereby the Effective Temperature or condition of body sensitive comfort is changed. It is calibrated in degrees Effective Temperature and also marked with the summer and winter optimum comfort lines. The instrument is provided with low, high and moving contacts of pure silver, for connection to temperature equipment (either heater or cooler or both) and similarly for connection to humidification or dehumidification equipment. It can be used on the 2- or 3-wire control systems. All contacts will carry 25 watts at voltages up to 110 a.c. or d.c. Magnetic snap action insures clean and positive make and break. No relays are required for solenoid valves, motorized valves, damper-motors and other light-load devices. Relays or devices for use on heavier loads are available. The instrument is 8¾" high, 5⅞" wide, 2¼" deep, and weighs 40 oz.



Radiation Receiving Tube

Thwing Instrument Co.

FOR permanent mounting where service is severe this new water-jacketed receiving tube combines a standard Twing conical-mirror type tube with a cast brass chamber in which the thermo-elements and lens are assembled and surrounded by a water jacket. Water inlet and outlet are ⅜" I.P.S. Overall length 12½". Water jacket section 3⅜" diam. This new receiver not only multiplies the accuracy-life of the elements but eliminates or minimizes some sources of errors in temperature measurements.



Trofimov's Problem Folder

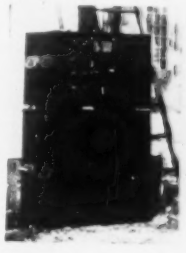
L. A. Trofimov

THERE are only two fundamental types of problems with which an engineer ever comes into contact: discovery type problems, leading to discovery, generally known as research problems; and invention type, leading to invention, generally known as development problems. The discovery type problem requires to find the cause of the known effects and the general procedure of it is the well known scientific method. The invention type problem requires the production of the desired effect from known causes and its procedure is the reverse of the Scientific Method, with some modifications. To help the engineer solve the invention type problems, Trofimov's Problem Folder has been put on the market. Its size and shape are identical with the ordinary letter size folder. Its purpose is two-fold: first, an engineer is recommended to keep in it his notes and sketches on the pending problem, and second, whenever he is in difficulty as to how to properly proceed on his problems, he is advised to read the instructions printed on the four pages of the folder. This guide consists in a detailed description, claimed to be scientifically correct, of the inventive type mental procedure leading from problem to solution. This procedure is simply a description of the natural way the normal mind travels from problem to solution. It claims to enable the user to reach all possible solutions of a technical problem and is entirely practical so that it may be easily followed by the average engineer.

Portable Schering Bridge

By C. F. Hill, T. R. Watts and G. A. Burr*

DESIGNED primarily for power factor, dielectric loss and capacitance tests on condenser bushings in circuit breakers and transformers, this new portable Schering bridge is also adaptable to the testing of equipment of higher capacitance, such as cables, and for miscellaneous laboratory uses. Earlier power factor tests on bushings have been made in the field, but this is probably the first application of the Schering bridge to field tests. The instrument is a Schering bridge designed for "inverted" operation, to permit testing capacitors having one terminal grounded. The testing potential is 13.8 kilovolts, which has been found adequate for finding faults, even in 230 kv. bushings. The manually operated decade resistors, decade capacitors, shield balancing controls, galvanometer, and all the parts which in conventional laboratory bridges are very near ground potential, are at 13.8 kv. potential from ground in this set. Therefore, they are enclosed in a metal box or shield which is balanced to galvanometer potential, and this box is enclosed in a grounded box. The knobs on the front panel are connected to their respective instruments by insulating shafts which have metallic bearings on the inner panel or shield to prevent shaft leakage currents from entering the bridge circuit. The new design includes a no-loss standard capacitor in the upper cabinet which utilizes the capacitance between the inner and outer boxes. A strip around the ends, top and bottom of the inner box comprises the active electrode, while the front and back serve as guard rings. The transformer and the low-voltage switching are mounted on the table which supports the instrument case. The cable which connects the set to the high voltage terminal of the capacitor under test has an inner shield which is balanced to the same potential as the central wire, thus eliminating losses from wire to shield; and also has an outer shield which is grounded. A reflecting vibration galvanometer is used because of its simplicity and its sensitivity to the fundamental frequency only. If desired, the set can be made convertible for use in the conventional laboratory manner (*i.e.*, not inverted, but with ground at instrument end), for testing at voltages above 13.8 kv., with auxiliary standard capacitor and transformer designed for the voltage to be used. The inverted Schering bridge is operated in the same manner as the conventional laboratory type. It is believed that a satisfactory device has been developed which will do the work quickly and with relatively little trouble. The use of the device, in cooperation with the manufacturer of the apparatus under test, will provide experience in the location of insulation troubles and permit the user to detect defective equipment in time to prevent outages, and thus reduce operating expenses.

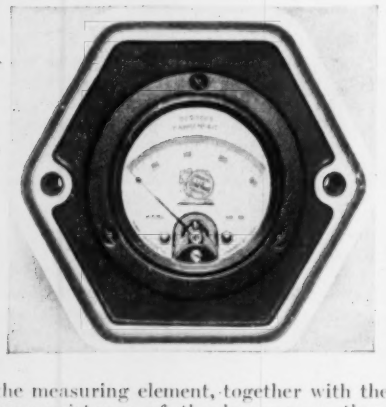


*Westinghouse Electric & Mfg. Co. Extract from paper presented before A.I.E.E. on January 25, 1934.

"Hold Heet" Pyrometers

Russell Electric Co.

DESIGNED, constructed, "priced and sold strictly for . . . use as standard equipment on heat-using machines," these new pyrometers are self-contained, the thermocouple extending directly from the hexagonal-cased indicator to the point of temperature measurement in the oven, furnace, kettle, etc. Thus, there are no "connection leads" but the "extension leads" may be attached to the top, bottom or either side of the 5⅝" case as specified. Alternatively, the "Hold Heet" pyrometer may be supplied in the form of a portable straight lance with aluminum handle. A distinctive characteristic is the 10-ohm resistance of

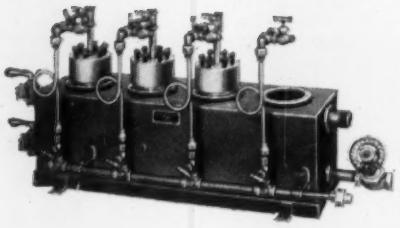


the measuring element, together with the low resistance of the heavy-gage thermocouples. The total variable external resistance is said to be $\frac{1}{150}$ of the measuring-element resistance, and the different couples are all so nearly alike in ohmic values that the instruments are uniformly calibrated for their average resistance. This mass-production method is said to give a maximum possible error of "even less than one part in 150" and it has made it possible to produce rugged pyrometers "at unheard-of low prices" especially for manufacturers of heat-process equipment. Two standard ranges have been announced: 60-800°F. and 60-1600°F.

Tilting-tank Steam Traps

Nason Mfg. Co.

THE new line of "Detroit" steam traps includes the return, vacuum, combination, and separating types. *Principle:* Tilting tank, mounted eccentrically on hollow trunnion, is held in horizontal position when empty, by means of large counterweight. When tank fills with water (through hollow trunnion), counterweight is over-balanced, and tank tilts, actuating the valves. *Claims:* "Not only traps condensed steam, but permits condensation to be turned into live steam with smallest possible use of fuel; uses same volume of steam as volume of water fed to boiler; does not require lubrication; has only two valves, both in plain view (packed without taking trap apart); able to handle water and return it to boiler at temperature as high as 335°F.; when used instead of pump, can increase thermal efficiency of plant by returning condensate hot, by as much as 20%; counter records number of operations, allowing accurate check on feed water and heating surface, boiler horsepower and heater capacity."



Gum Test Baths

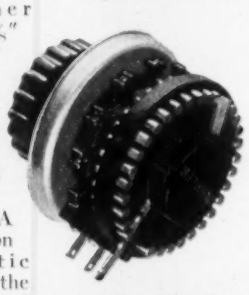
American Instrument Co., Inc.

ARMY and Navy specifications for testing gum stability of gasoline are met by the newly announced series of electrical and steam heated gum baths, supplied for one, two, or four bombs, in either style of heating. The bombs, which take an 8-oz. sample bottle, are of new design, with stainless steel closure plates, and means for sealing without the use of a large wrench. Used at 100 lbs. oxygen pressure, they are guaranteed to stand 2000 lbs. Heavy cadmium plating protects the body of the bomb from corrosion.

Ladder Type Attenuators

Remler Company, Ltd.

SAID to meet the most exacting voice circuit requirements for transmission, recording and projection, these newly designed ladder type attenuators mount either through a 2⅜" hole or by means of 3 screws through the panel. Attenuation is increased in 53 steps of 0.75 db. each to 45 db. A rising attenuation characteristic serves to fade the program from 45 db. to infinity. Flat frequency characteristic from 20 to 20,000 c.p.s., low noise level, and heavy laminated wiping contact arm are features. The unit is enclosed in an aluminum shield 2 $\frac{5}{16}$" deep. Standard impedances are 50, 200 or 500 ohms; other values on order.



Three-way Tempering Valve

Lawler Automatic Controls, Inc.

FOR submerged coil type heaters, instantaneous coils and domestic hot water storage tanks, this new thermostatic valve or mixture regulator is said to eliminate delivery of excessively hot water. It is supplied with hot water from the coil and with cold water from the mains. A sensitive thermostat located in the mixing chamber controls the amount of cold water necessary to temper the delivered hot water to the desired temperature. The thermostat is of the liquid-expansion type, is made of brass or copper and is said to exert ample power to operate positively the valve controlling the hot and cold water ports. The standard Lawler Thermostatic Tempering Valve is designed to deliver water at any desired temperature between 140 and 170°F. with boiler water temperature kept at >180°F. Adjustment requires use of a wrench. Standard sizes are 1", 1½" and 2".

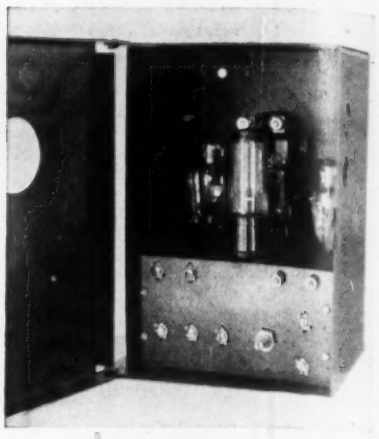


Fig. 1

Photoelectric Relay

Westinghouse Elec. & Mfg. Co.

IN such applications as counting, the operating speed of the new "LE" relay is extremely fast, ranging from 200 to 600 objects per minute depending upon amount of light change available and resistance of contacts. The heavy-duty contactor interrupts 20 amps., 115 volt a.-c. non-inductive load or 3 amps., 115 volt d.-c. The relay itself is housed in a sturdy steel box (Fig. 1) with knockouts for lead-in wires. Phototube housings (Fig. 2) can be mounted on standard rigid conduit or flexible armor, splashproof housings being available for outdoor work, etc. Suitable light sources are available. Gas or vacuum phototubes can be used. Flexibility in design allows either on or off operation of contactor. Standard a.-c. unit works on any frequency from 25 to 60 cycles with equally high sensitivity throughout the range—said to be a new characteristic.

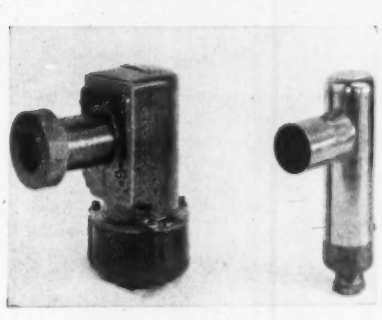


Fig. 2

Demand Meter Register

General Electric Co.

NEED for servicing has been minimized in this completely new demand meter register, which can be applied to eight different types of G-E watthour meters. A new testing device, also announced, permits an overall "accuracy" check of the register in about a minute, is adapted for manual operation and is said to be fool-proof and time saving. Illustration shows method of attaching it. An improved type of high-torque Telechron timing motor permits the use of high torques and safety factors. Provision for refilling the motor barrel with oil is a new feature which contributes to long life. The motor can be removed by loosening two screws only about one turn. In the resetting mechan-

ism the follow-up principle is used. Full motor torque is available automatically if needed to insure positive reset. This gives double protection against faulty reset. The interval indicator, together with the over-running clutch which permits manual reset, is said to be an important feature in testing. Need of adjustments has been minimized, and those that are required are in plain view; all bearings are permanently located; all materials corrosion resisting. The 6½" scale is limited to 180° in order to locate the register entirely above the disk, thus facilitating checking and allowing free inspection of the magnet gap.

Radio Station Control

General Electric Co., Westinghouse Elec. & Mfg. Co. and RCA-Victor

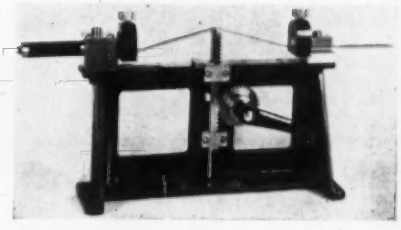
THREE companies collaborated to design and build the equipment for the new 500-kw. Crosley Station WLW, which is said to be outstanding

in numerous respects. There are more than 70 tubes in the complete transmitter. The audio output delivered by the modulator is approx. 165 db. above microphone output—a power amplification of 7×10^{16}. The control circuit was designed for complete automatic operation and for any desired degree of manual control by means of 30 centrally located controls on the desk-like unit (General Electric Co.) illustrated, which has 35 lights to indicate the functioning of the various circuits.

Paper Stretch Tester

Thwing Instrument Co.

REPRODUCIBLE determinations of the amount of stretch in paper when tested to the breaking point are made possible by this new instrument which takes specimens 15 mm. (approx. 0.6") wide but has a movable jaw



so that the specimens can be either 6" long or 4" long, depending upon their nature. To insure testing under uniform conditions, the test piece is held taut by an initial loading of 1 kg. The paper is stretched by a movable stretching bar, which is moved in a vertical plane by a rack and pinion until the paper breaks. A scale on the stretching bar indicates in inches how much the test piece of paper is deflected when subjected to a maximum constant stretching action. The Thwing Stretch Tester thus has a geometrical magnification to produce the stretch dimension, instead of mechanical magnification which is said to introduce errors. All grades of paper can be tested in the Thwing Stretch Tester but the outstanding field for its use is said to be testing papers that are to be corrugated, embossed, or hot or cold pressed.

Self-starting Time Switch

Paragon Electric Co.

SMALL, compact and simplified, Type G Series Self-starting Synchronous Time Switch has been developed for operating single and dual thermostats; stoker, draft, oil-burner, machinery and traffic controls; neon signs, etc. in circuits <1600 watts. Size: 8"x4"-x3" said to be the most compact on the market. Self-starting synchronous motor is self-lubricating with gears in dust-proof shell. Between it and the removable Paragon dial there are no friction slips—a feature said to eliminate many troubles. Series G is being produced for such users as manufacturers and distributors on a contract basis.

"Paper Hygroscope"

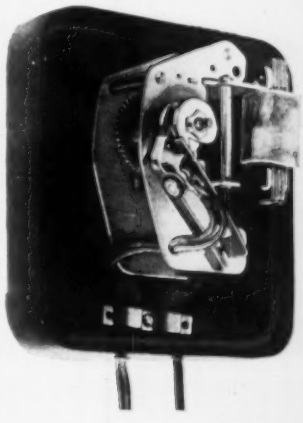
Lithographic Technical Foundation, Inc.

IN contrast with usual types of hygrometers and moisture meters, this new instrument is designed primarily to indicate whether or not the pile of paper (or other hygroscopic material) into which it is inserted is *in hygrometric equilibrium with the atmosphere of the room.* It does not measure moisture content, except by inference, but an additional use is to test for moisture content on an arbitrary scale and thereby determine the relative fitness of the paper in various lots. Where humidity is not controlled the Paper Hygroscope can be used also to test lots as received and to guide pressmen on multi-color work. In appearance it resembles a sword with a dial between the handle and the long thin blade which is perforated toward the point. To use: wave in air, turn dial edge to bring pointer opposite mark, insert in material, wait one minute, see whether pointer has remained between tolerance arrows.

Variable Repeating Interval Timer

Walser Automatic Timer Co.

THE new "Jewel No. 10-630-S" timer is designed for use on electrical equipment requiring continuous interval operations and using not more than 3 amps., or to operate a relay carrying heavier currents. A small, non-



synchronous 110-volt a.-c. motor revolves a shaft at the rate of 30 minutes to the cycle through a train of gears. Two cams are mounted on this shaft: the rear cam permanently attached, the fore-cam on friction and adjustable in relation to the rear cam to provide any circuit-closing period between 1 sec. and 8 min. in a full cycle of 30 min., continuing to repeat as long as current is delivered to the motor. The cams operate a quick make-and-break single-pole switch with silver contacts. The mechanism is mounted on a cast-iron base with screw holes in corners. A groove in this base holds a rubber gasket on which the sheet metal cover rests, making a dust-proof housing which measures 4" x 4" x 2½" when closed.

Novel Voltage Regulator Control Element

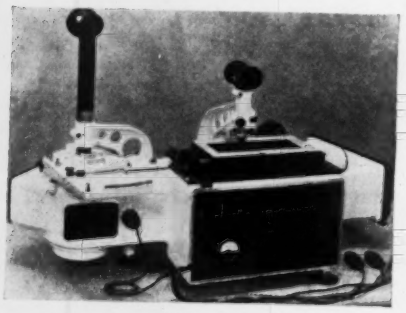
Westinghouse Elec. & Mfg. Co.

IN one respect the many forms of generator voltage regulators are similar: Each must have a control element connected to the voltage to be regulated which detects variations and commends the corrective element. To meet the need for an unusually rugged control element for use on naval vessels, which has to be accurate in spite of gun fire, there has been developed a new element which resembles, in some respects, a dynamic loud speaker. There is a stationary coil with a moving coil held on a pivoted arm. The forces developed are relatively high so that rugged parts may be used without impairing the required accuracy. Movements of the pivoted arm set up pilot circuits which bring about correction. This element is said to be equally useful for industrial regulating applications—a.c. or d.c.

Recording Densitometer

The R. Y. Ferner Co.

DUE to the short period of the mirror a high speed of automatic recording is obtained with this new instrument of the Société Genevoise d'Instruments de Physique: 15 cm. per minute on the diagram. This speed is obtained by a strong amplification of the photoelectric current, which can accordingly be measured with a sturdy milliammeter of short period instead of an ultra-sensitive galvanometer of long period. Amplification is independent of storage battery fluctuations. Records can be made in full daylight. Apparatus requires no accessories. Omission of primary slit makes operation easier and unaffected by dust. *Principle:* A very narrow light beam is directed through the photographic plate to be analyzed and received on a photocell, the output of which is amplified by a double-grid vacuum tube and measured by a milli-



ammeter of standard design, which is rotated about a vertical axis over angles strictly proportional to the linear displacement of the plate, the available magnification of the abscissae being 3, 4, 5, 8, 10, 15, 20 and 50X. The photographic plate carrier is moved 100 mm. by automatic travel, can be shifted an additional 90 mm. by hand, and has a transverse adjustment of 70 mm. to bring different spectra into the path of the beam. The paper sheets used are 120x300 mm. with a useful surface of 110x290 mm. They are carried by a frame with a window and held against a cylindrical surface by spring pressure. A frame with translucent screen can be used for visual observation and adjustment. The primary light source is a straight filament, the image of which is reduced 10 times in its projection on the plane of the photographic plate so that the maximum width of the sharp luminous image averages only 0.02 mm. and a fine analysis of the blackening is made in an area less than 0.01 mm. in width. If, because of the grain of the plate, a coarser analysis is desired, this is obtainable by making the image on the plate broader. A Hartmann screen permits controlling the length of the secondary slit between 0.1 and 1.2 mm. of the light spot on the plate. The primary and secondary objectives are both adjustable. For special work the amplification factor can be modified by interchanging the resistance mounted in series with the photocell, generally 10 megohms. The instrument can be used for examination of all kinds of spectrograms, ray and continuous spectra, absorption bands, X-ray spectra, etc., also of multiple rays, and for study of photographic materials, sharpness of images, size of grain and similar problems.

INSTRUMENTS BOOK SHELF

Fluid Meters—Their Selection and Installation. Part 3 of the Report of A.S.M.E. Special Research Committee on Fluid Meters. American Society of Mechanical Engineers, New York, 1933. Paper, 8x10½ inches, 44 pages. Price $1.50.

This, the concluding part of the committee's report, crowns the 18 years of efforts of R. J. S. Pigott who has been its chairman since its formation in 1916. It also testifies to the labors of J. R. Carlton, chairman of the subcommittee which has been preparing this part since 1927. It is greatly condensed, but not uniformly. There are 35 pages of text, and more than half of it is devoted to orifice meters. The brief Section I, "Selection of Type of Meter," is a fine job except for its inadequate treatment of positive meters (see below); at any rate it includes a nearly flawless gem: paragraphs 7 to 23 on properties of the fluid and characteristics of the flow to be measured, which pack into two pages a large amount of useful information never before presented so clearly. Their style is better than that of most of the other portions of the report, so that the reader is shocked to come across such an ambiguity as "raising the viscosity by heating the liquid" (par. 21). Section II on Installation is longer; 17 of its 21 pages are devoted to orifice and nozzle meter installations, which however represents a skillful condensation of the large amount of material published on this subject, the writers pointing out every essential precaution in a minimum of words. I say a minimum of *words* because these pages are mostly diagrams, three taking up a full page each. The index is such a thorough job that I recommend making it a complement to the main text of the next edition. This could be done without greatly increasing the number of lines of type, by inserting quantitative data between brackets. Example, in the 25 lines under "Accuracy."

Little space is allotted to positive meters of all classes and types, and it is a pity that the distinction between positive and inferential meters has been dropped. One of Pigott's distinguished achievements in science and engineering was his *dual* scheme of classifying all fluid meters (*a*) into positive and inferential and (*b*) into quantity and rate. Since he designed these twin lighthouses 18 years ago they have obsoleted all other schemes. Yet the writers of Part 3 harp on the somewhat tenuous division into quantity and rate meters, and fail to mention the valid distinction between positive and inferential meters. It is with reluctance that I venture to attack this outstanding innovation presented in Part 3, but a radical departure from what has almost become an engineering standard cannot be passed by without notice. Besides, the relative importance of "P & I" and "Q & R" is not a mere academic question of nomenclature as in botany, but it is a practical matter of semi-officially labeling the various classes of fluid meters. The A.S.M.E. "P & I" classification has become an influence in the selection of meters. In my opinion it should have been re-affirmed in Part 3 which deals with "*Selection* and Installation." Indeed it should have been made more explicit than in Part 1 which, all through its successive editions, has never contained a word to explain that some meters belonging to the positive division by virtue of their type may be imperfectly positive by reason of their design and construction. It may have been this silence in successive editions of Part 1 —this *unqualified* labeling, for example, of even a cheap imported disk meter as "positive" because it belongs to the "volumetric" class — that riled some advocates of inferential meters. And they weren't the only objectors: engineers interested in the better grades of positive meters wanted the Committee either to be more explicit or to abolish the "P & I" distinction. It may well be that if the latest edition of Part 1 had *explained* P & I the abolitionists would not have triumphed so completely in the final wording of Part 3. Their victory implies that the new classification will be used in the next edition of Part 1. It means, then, that a great engineering society, which erected a useful pair of lighthouses, is apparently about to allow one of them to be demolished instead of increasing its candle-power.

Since I proposed the "degree of positiveness" criterion, some discussers have made much of the doctrine that there are no ideally positive meters. I grant it for the sake of argument, but what is of greater importance to an "engineering code authority" is that there are no meters that are neither positive nor inferential. Moreover, the "P & I" scheme applies to the entire meter whereas the "Q & R" scheme is *not an engineering classification of meters* but is a classification of *primary elements*. All in all, "Q & R" is less significant than "P & I" and its significance wanes with the appearance of every new Q meter with an R primary and of every new R meter with a Q primary, while the likelihood of the appearance of a new type of meter unclassifiable as either P or I grows dimmer. If Pigott's shining "P & I" beacon is extinguished, his somewhat less logical "Q & R" (which derives most of its usefulness from being one of the twins) may have to undergo drastic alterations.

The treatment of positive meters (never called such) is well-nigh scornful. Under "General Considerations" there are five brief paragraphs on "quantity meters" and four of them contain questionable assertions. To wit:

[45] "They are not suitable for metering dirty liquids unless strainers can be placed in the main line preceding the meter." On the contrary, tilting-bucket meters are frequently found to be the *most* suitable for metering dirt- and sediment-laden liquids.

[46] "Readings obtained . . . may be satisfactory for bookkeeping purposes, but not as an aid to operation." In point of fact there are industrial processes where the quantities are all-important and where the rates do not matter.

[47] "Their use is usually limited to small or medium sized lines. In a few instances, quantity meters of large capacity are manufactured, but in such cases the installed cost is quite high compared with that of a rate meter for the same service." The first assertion is saved by the word "usually"; the second is in error: most rate meters are unsuitable for "the same service" if it is the measurement of a wide range of flows, and a specially-built rate meter installation for wide-range service would usually cost more than a quantity meter and give more trouble.

[49] "The meter body of a quantity meter contains both the primary and secondary elements." Let's be charitable and assume that the word "usually" was left out by the typist: there are industrial types in which the body is separable from the register, chart recorder and other instruments. Why, in some types, the body is *remote* from the instruments!

The 56 brief paragraphs on "quantity meters" under "Specific Details" can stand revision, too. One splendid innovation, though, is that liquid meters and gas meters are at last discussed separately. Paragraphs 71 to 77 on liquid meters of the "disk, piston, rotary piston and oscillating piston" types should be revamped entirely to inform the reader about the difference between the characteristics of reciprocating piston meters and those of oscillating piston, rotary piston and nutating disk meters. And even the reciprocating piston meters might well be divided for discussion into 5 or 6 types, to justify the heading "Specific Details." This same remark applies, as I have broadly hinted, to the brief discussions of nearly all meters other than head meters.

If you are considering *various* classes of meters, you will find this report to be less than a general and comprehensive guide to their "Selection and Installation," but with reference to orifice, nozzle, Venturi and Pitot metering, you will find it the most valuable handbook issued in recent years.

M. P. Bénar

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of instruments and devices for measurement, inspection or control

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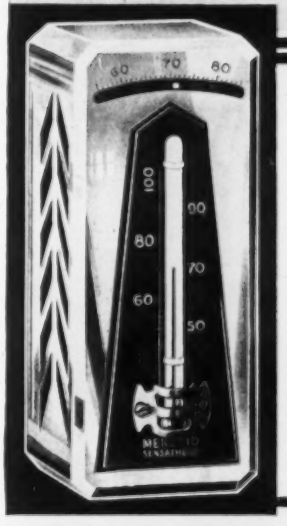

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